The emergence of photovoltaics in France in the light of feed-in tariffs: exploring the markets and politics of a modular technology

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The emergence of photovoltaics in France in the light of feed-in tariffs
Exploring the markets and politics of a modular technology

L'émergence du photovoltaïque en France à la lumière des tarifs d'achat
Exploration d'une technologie modulaire entre politiques et marchés

Sous la direction d'Alain Nadaï, Directeur de recherche CNRS

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"Yellow sun is shining in the afternoon
I'd really like to tell you but I feel it's too soon
My actions are dictated by the phase of the moon"
The Raconteurs—*Yellow Sun*

Il est de rigueur, après avoir passé plusieurs années à travailler sur une question dont pas grand monde n'a plus qu'une vague idée, de se rendre compte que ce n'était pas un exercice si individuel qu'on croyait. L'écriture des remerciements qui accompagne cette prise de conscience est très technique (Brunelle, 2014, communication personnelle), puisqu'elle revient finalement à décrire la thèse comme un agencement socio-technique résultant du concours de nombreux médiateurs. Mais, étant donné qu'il y a trois catégories de personnes, celles qui lisent la thèse, celles qui lisent les remerciements, et celles qui ne lisent rien du tout (Gasser, 2014, communication personnelle)[1], je n'irai pas plus loin dans l'usage du jargon sociologique afin de ne pas effrayer la deuxième catégorie.

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Résumé en Français

Depuis le début des années 2000, le photovoltaïque a connu une expansion sans précédent sous l'impulsion des politiques européennes de développement des énergies renouvelables et notamment des tarifs d'achat. Autrefois cantonnées à l'alimentation électrique de sites isolés, les technologies photovoltaïques se sont déployées sur le marché de masse de production d'électricité. Si leur contribution y reste encore marginale, leur essor est frappant par sa rapidité et par les turbulences qu'il a entrainées, ainsi que par la relation qu'il entretient avec les instruments politiques qui l'ont déclenché et entretenu. En France comme dans de nombreux pays européens, le photovoltaïque, considéré comme simplement prometteur il y a quelques années, est désormais devenu problématique à plus d'un titre. Les années 2008 à 2012 ont été un moment charnière de cette transformation.

Le travail présenté dans cette thèse a démarré en 2010, en plein cœur de cette période de tourmente : un mois après son début, le système de soutien au photovoltaïque en France était remis en cause et le secteur bouleversé. Partant de la perplexité provoquée par ce brutal renversement de situation, la thèse mobilise les outils développés par la sociologie de la traduction et la sociologie des agencements marchands pour explorer les dynamiques souvent paradoxales de l'émergence du photovoltaïque sur des marchés dépendants d'un soutien politique. L'accent est mis sur deux caractéristiques qui font du photovoltaïque un objet singulier : le caractère modulaire et émergent des technologies photovoltaïques d'une part, leur déploiement sur des marchés régulés d'autre part. Cela se traduit d'abord par une attention à la matérialité du photovoltaïque et des agencements marchands et politiques dans lesquels il est pris : comment la modularité du photovoltaïque est-elle saisie et quels sont ses effets ? Cela amène ensuite à redéfinir le tarif d'achat, instrument principal de l'émergence du photovoltaïque connecté au réseau, à la lumière de ce qu'il fait et de ce qu'il fait faire.

La réflexion présentée dans cette thèse se déroule en deux temps. Les deux premiers chapitres s'attachent à spécifier dans un même mouvement l'objet d'étude et l'approche adoptée pour le saisir. Les chapitre trois à cinq suivent cet objet – le photovoltaïque attaché à son tarif – sur trois terrains et à trois grains d'analyses différents.

Le chapitre 1 déploie une gamme de concepts et notions centraux dans la sociologies des sciences et des techniques (STS) et les théories de l'acteur-réseau (ANT) afin de saisir le photovoltaïque comme une technologie à la fois émergente et modulaire. Parce qu'elles ont été développées pour analyser des situations d'innovation ou de controverse, ces approches fournissent des outils conceptuels pour l'étude de processus en train de se faire et d'objets non stabilisés tels que le photovoltaïque. La redéfinition de l'action comme relationnelle qu'opère la théorie de l'acteur-réseau permet de caractériser le photovoltaïque comme objet multiple, partiellement constitué par les assemblages dans lesquels il est pris. On montre que la modularité du photovoltaïque a deux implications : d'une part, parce que les modules photovoltaïques encapsulent une fonction stabilisée (celle de produire de l'électricité à partir du rayonnement solaire), ils peuvent circuler rapidement et à grande échelle ; ce faisant, ils peuvent s'insérer dans une large gamme de systèmes photovoltaïques, donnant lieu à un foisonnement de formes de photovoltaïques dont les contours sont difficiles à déterminer.

Afin de mieux comprendre la prolifération récente du photovoltaïque, **le chapitre 2** se penche sur les tarifs d'achat qui ont largement contribué à la déclencher. Après être revenu sur les notions de dispositif et d'agencement socio-technique, il définit les tarifs d'achat photovoltaïques comme des agencements à la fois marchands et politiques. Les perspectives de sociologie de la traduction sur la mise en marché et sur la mise en politique y sont croisées pour caractériser les tarifs d'achat photovoltaïque comme des agencements débordés à dessein. Les tarifs d'achat y sont ainsi redéfinis comme des agencements marchands qui cadrent et stabilisent les transactions d'électricité solaire de façon à déclencher un processus d'innovation et d'expérimentation autour des technologies photovoltaïques. La singularité des tarifs vient de ce que l'équilibre entre contrôle et inventivité qui est au cœur de leur fonctionnement en tant qu'agencements marchands est, en dernier recours, calibré et régulé politiquement.

Le chapitre 3 retrace l'émergence des tarifs d'achat comme instrument de soutien aux énergies renouvelables puis au photovoltaïque en Europe à travers l'étude conjointe des orientations de l'Union Européenne, des politiques des États membres et des investigations académiques. Il part de leur apparition dans les années 1980 comme moyen d'insérer l'électricité d'origine éolienne sur le réseau existant au Danemark et en Allemagne, avant de se pencher sur leur constitution en tant qu'agencements de marché dans le cadre de l'élaboration de la politique européenne des énergies renouvelables. Initialement pensé comme devant contribuer à l'intégration du marché interne de l'électricité, le développement de marchés pour les énergies renouvelables en Europe a donné lieu dans les années 2000 à une expérimentation grandeur nature autour des instruments de soutiens aux ENR qui se mettaient en place dans les États membres. Au cours de ce processus piloté et documenté par les institutions européennes, les instruments de soutien aux renouvelables se sont sophistiqués et affinés et les tarifs d'achat affirmés comme instrument dominant, jusqu'à ce que les turbulences liées au développement rapide du photovoltaïque ne viennent les remettre en question.

Le chapitre 4 déplace la focale sur le cas français. Il étudie comment la mise en marché du photovoltaïque en France a déclenché sa politisation brutale. Une première section revient sur l'histoire du soutien au photovoltaïque en France et plus particulièrement la mise en œuvre des tarifs d'achat entre 2000 et 2013. Elle analyse les agencements de marché que les réformes successives des tarifs d'achat ont mis en place. Une deuxième section est consacrée aux effets concrets de ces tarifs, et plus particulièrement au dérapage du système de soutien entre 2008 et 2011. Elle est centrée sur l'analyse de la période du moratoire et de la concertation sur les tarifs d'achat, entre décembre 2010 et mars 2011. L'inflation et les débordements du secteur, que des révisions ponctuelles du cadre tarifaire ne sont pas parvenues à endiguer, a amené le gouvernement à suspendre le système d'incitation pour le mettre en discussion dans ses dimensions politiques. Ce processus, dont on tente ici de rendre la dimension dramatique et désordonnée, a permis la constitution du secteur du photovoltaïque comme public et comme groupe d'acteurs non plus seulement économiques mais politiques ; comme on le montre, il s'est néanmoins soldé par une tentative de dépolitisation à travers le tarif qui illustre l'ambivalence de l'instrument.

Le chapitre 5 s'intéresse également à la façon dont le tarif d'achat met en mouvement, mais adopte une perspective bien différente. Il est consacré à un projet de centrale solaire mutualisée mené par une coopérative agricole du Lot entre 2008 et 2010. Outre son ampleur, la particularité de ce projet a été de se saisir du tarif d'achat au moment où il était le plus élevé pour le constituer en opportunité collective et le transformer en outil de développement territorial. C'est la sécurité d'investissement garantie par le tarif d'achat, combinée aux possibilités qu'offre la modularité du photovoltaïque, qui intéresse la coopérative et l'équipe pour s'affirmer en tant qu'acteur énergétique territorial. Cependant, en retraçant les épreuves et les reformatages nécessaires à la réalisation du projet, le chapitre montre que la conversion de l'opportunité constituée par le tarif d'achat en ressource n'est ni immédiate, ni garantie. Ce n'est au terme d'une aventure risquée et de l'enrôlement de nombreux partenaires que la coopérative peut se considérer habilitée par le tarif en tant qu'acteur du marché des énergies renouvelables et, dans une certaine mesure, porteuse d'une innovation politique (ou du moins organisationnelle).

English summary

Since the early 2000s, photovoltaic has undergone an unprecedented growth driven by European renewable energy policies, and in particular feed-in tariffs. Photovoltaic technologies, once confined to isolated applications, have deployed on the mass market for electricity. Though their contribution to electricity generation remains marginal, their rapid and turbulent growth is striking. Its relation to the political instruments that have triggered and sustained it makes it all the more singular. In France as in many European countries, photovoltaic has turned from a promise to a multi-faceted problem. The years 2008 to 2012 have been pivotal in this transformation.

The research presented in this dissertation started in 2010, right in the middle of this time of turmoil: one month into the work, the French photovoltaic support scheme was brutally called into question, upsetting a booming market. Starting from bewilderment at this unanticipated turn of events, my dissertation relies on the tools developed by actor-network theory (ANT) and by the sociology of market *agencements* to explore the emergence of photovoltaic on policy-driven markets. It focuses on two characteristics that make photovoltaic a peculiar object of study: the emergent and modular character of photovoltaic technologies on the one hand, and their deployment on regulated markets on the other hand. This first translates into an attention to the materiality of photovoltaic and of the market and political *agencements* it is entangled in. How is the modularity of photovoltaic seized by those who develop it, and what effects does it trigger? It then lead me to reconsider feed-in tariffs, which have been the main driver of the emergence of grid-connected photovoltaic, in the light of what they do and of what they make happen.

The dissertation unfolds in two parts. The first two chapters specify at one time the object of study and the approach adopted to analyse it. Chapter 3 to 5 then follow this object – namely, photovoltaic entangled to its tariff – in three sites and at three distinct resolutions, analysing its economic and political effects.

Chapter 1 deploys a series of crucial science and technology studies (STS) and ANT concepts and notions. These help me define photovoltaic as an emergent and modular technology. Insofar as they were developed to analyse situations of innovation and controversy, these theories provide me with analytical tools for the study of things in-the-making and of non-stabilised objects such as photovoltaic. In particular, I consider the notions of hybrid forums (Callon, Lascoumes & Barthe, 2001), matters of concern (Latour, 2004, 2005) and issue (Marres, 2005, 2007). In the light of the works of Callon (1998, 2008), Law (2004), Gomart (2002) and Mol (Mol, 1999; de Laet & Mol, 2000), I use ANT's redefinition of action as heterogeneous and relational to characterise photovoltaic as a multiple object that is partially – but partially only – constituted by the arrangements it is entangled into. I thus show that the modularity of photovoltaic implies two things. First, as photovoltaic modules encapsulate a stabilised function (that of generating electricity from sunlight), they can circulate rapidly and on a large scale. In so doing, they can plug into a large diversity of photovoltaic systems, which generates a proliferation in the forms that photovoltaic can take. This makes photovoltaic difficult to delineate as an object of study.

In order to shed light on the recent proliferation of photovoltaic, **chapter 2** focuses on the feed-in tariffs that have largely contributed to trigger it. Drawing on Callon (2013), I first review the theoretical implications of the notions of sociotechnical *dispositifs* and *agencements*. I then rely on these notions to define photovoltaic feed-in tariffs as political and market *agencements*. ANT perspectives on marketisation (Callon, 1998; Callon et al. 2007; Muniesa & Callon, 2007; Caliskan & Callon, 2009, 2010; Breslau, 2013) and on politicisation (Barry, 2001, 2004; Callon, 2007; de Vries, 2007; Marres, 2005, 2007) are combined to characterise feed-in tariffs as *agencements* that are overflowed by design. I thus redefine feed-in tariffs as market *agencements* that frame and stabilise the exchange of photovoltaic electricity so as to trigger a process of innovation and experimentation around photovoltaic technologies. Feed-in tariffs are *agencements* that constrain the better to let go, and their success relies upon the balance they strike between control and inventiveness. Their originality stems from the fact that this balance is, in the last instance, calibrated and regulated at a political level.

Chapter 3 traces the making of feed-in tariffs into instruments for the development of renewable energy and, later, of photovoltaic in Europe. It studies jointly the evolution of political directions given by the European Union, of Member States renewable energy policies, and reviews academic research and expertise on the topic. I start from the apparition of feed-in tariffs in the 1980s as a mean to integrate wind power into existing electricity markets in Denmark and Germany. I then look at their constitution as market *agencements* in the context of the elaboration of European renewable energy policy. Initially meant as a way to contribute to the integration of the internal market for electricity, the development of renewable energy markets in Europe gave way to a process of scale-one experimentation as Member States implemented renewable energy support instruments and a 'network of experimentation' emerged (Callon, 2009) in the 2000s. During this process, which was steered and documented by EU institutions, renewable energy support instruments were refined and sophisticated. Instruments and theories about these instruments evolved jointly, making it hard to distinguish between "cook and recipe" (Holm & Nielsen, 2007). Feed-in tariffs emerged as the dominant form of support for renewable energy until the turbulences entailed by the rapid deployment of photovoltaic called them into questions.

Chapter 4 shifts the focus on the French case. It studies how the marketisation of photovoltaic in France eventually led to its brutal politicisation and its tentative articulation as an issue. The first section retraces the history off photovoltaic policy in France, and in particular the introduction of feed-in tariffs for photovoltaic between 2000 and 2013. In it, I analyse the market *agencements* that the successive reforms of the scheme set up. The second section is centred on the actual effects of these feed-in tariffs, and specifically on the way support went off-track between 2008 and 2011. I focus on the moratorium and consultation on feed-in tariffs that took place between December 2010 and March 2011, which I describe as a political moment as defined by Barry (2001, 2004), that is as the opening of new spaces of disagreement. I show how the uncontrolled inflation of the photovoltaic sector and the overflows that ensued led the government to freeze the incentive system and to re-open it as a political issue (Marres, 2007). I try to convey the dramatic and disorderly character of this process and stress how it enabled the photovoltaic sector to constitute as a public and a group of political – not just economic – actors. However, it ended with an attempt toward depoliticisation through the tariff, which stresses the ambiguity of the instrument.

Chapter 5 is also interested in the ways feed-in tariffs set people and things in motion. It adopts a perspective influenced by STS studies on innovation and entrepreneurship as processes of collective experimentation (Akrich et al., 2002; Doganova, 2009; Garud & Karnøe, 2003). It focuses on a mutualised photovoltaic project carried out by an agricultural cooperative in the Lot (Midi-Pyrénées) from 2008 to 2010. On top of its scale, what makes this project original is the way the cooperative seized the feed-in tariff at its peak and turned it into a collective opportunity and a resource for territorial development. The tariff provides high investment security; combined to the possibilities provided by the modularity of photovoltaic, it triggered the interest of the cooperative and equipped it to constitute itself as a territorial actor in the energy sector. By retracing the trials and reformatting that were necessary to carry out the project, the chapter shows that the conversion of the tariff opportunity into a resource cannot be taken for granted. Only at the outcome of a risky adventure, and after having enrolled several partners can the photovoltaic-equipped cooperative come out as a player on renewable energy markets and, to an extent, the promoter of a political innovation.

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ADEME: Agence de l'environnement et de la maîtrise de l'énergie
AIPF: Association des Industriels du Photovoltaïque Français
ANT: Actor-Network Theory
APESI: Association des Producteurs d'Electricité Solaire Indépendants
BDI: Bundesverband der Deutschen Industrie
BIPV: Building-Integrated Photovoltaïque
BOS: Balance of system
CARD: Contrat d'accès au réseau de distribution
CDC: Caisse des Dépôts et Consignations
CEIAB: Comité d'Evaluation des produits photovoltaïques Intégrés Au Bâti
CODOA: Certificat ouvrant droit à l'obligation d'achat
CRAE: Contrat de raccordement, d'accès au réseau et d'exploitation
CRE: Commission de Régulation de l'Energie
CSPE: Contribution au Service Public de l'Electricité
CUMA: Coopérative d'utilisation du matériel agricole
DDT: Direction départementale des territories
DGEC: Direction Générale de l'énergie et du climat
DGEMP: Direction Générale de l'Energie et des Matières Premières
DGT: Direction Générale du Trésor
DREAL: Direction régionale de l'environnement, de l'aménagement et du logement
EDF: Electricité de France
EDF-AOA: Electricité de France Agence obligations d'achat
EDF-EN: EDF Energies Nouvelles
EEG: Eneuerbare Energien Gesetz (Renewable Energy Law)
EPIA: European Photovoltaic Industry Association
ERDF: Electricité Réseau Distribution de France
EU ETS: European Union Emission Trading Scheme
EU: European Union
FIT, FITs: feed-in tariffs
FNE: France Nature Ennvironnement
GAEC: Groupement agricole d'exploitation en commun
Gimélec: Groupement des industries de l'équipement électrique, du contrôle-commande et des services associés
GPPEP: Groupement des Particuliers Producteurs d'Electricité Photovoltaïque
IEA: International Energy Agency
IPCC: International Panel on Climate Change
LCO(R)E: Levelized Cost of (Renewable) Electricity
MEDDE: Ministère de l'Ecologie, du Développement Durable et de l'Energie
MEDDTL: Ministère de l'Ecologie, du Développement Durable, des Transports et du Logement
MEEDAD: Ministère de l'Ecologie, de l'Energie, du Développement et de l'Aménagement Durable
MEEDDAT: Ministère de l'Ecologie, de l'Energie, du Développement Durable et de l'Aménagement du Territoire

MEEDDM: Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, chargé des Technologies Vertes et des Négociations sur le Climat
MEFI: Ministère de l'Economie, des Finances et de l'Industrie
NFFO: Non-Fossil Fuel Obligation
NGO: Non Governmental Organisation
PPI: Programmation pluriannuelle des investissements
PTF: proposition technique et financière
PURPA: Public Utility Regulatory Policies Act
PV: photovoltaic(s)
R&D: Research & Development
RE: renewable energy
RES-E: electricity from renewable energy sources
RET: renewable energy technologies
RPS: Renewable Portfolio Standards
SAS SAES: Société à action simplifiée Ségala Agriculture et Energie Solaire
SER: Syndicat des énergies renouvelables
SER-Soler: photovoltaic branch of the SER
SET Plan: European Strategic EnergyTechnology Plan
SICASELI: Société d'intérêt collectif agricole du Ségala Limargue
SRREN: Special Report on Renewable Energy
StrEG: Stromeinspeisungsgestez (Feed-in Law)
STS: Science and Technology Studies
TGC: Tradable Green Certificates
TPAMPS: Touche pas à mon panneau solaire!
VDEW: Verband der Elektrizitäswirtschaft
VIK: Verband der Industriellen Energie und Kraftwirstschaft

Foreword

This dissertation relies on material in both English and French.

For interviews excerpts and citations from primary sources, I have included translations in English in the main text; original transcriptions are provided as endnotes. Interviewees are anonymous, except in a few cases when they agreed for their name to be used.

For academic literature, whenever possible, I have preferred to include original citations in the main text, so as to avoid possible mis-translations; English translations of French texts are then provided as footnotes.

A glossary of the key theoretical terms informing this work is provided after the conclusion.

Introduction

> "When you've been in the field for a while and you look at it from an industrial perspective, the dynamic of photovoltaics is really amazing. I learn more every day. It moves at such incredible speed! Indeed, adapting a feed-in tariff system – or any form of support – to this kind of industry, to this type of dynamic, it certainly requires a bit of thought. No doubt, it takes some skill. You have to believe in it, you have to want it, you have to try to understand it."
> Interview 3

From a promise to a problem

In 2010, when the research presented in this dissertation started, photovoltaics were still mostly a promise, and especially so in France. Their actual contribution to electricity generation was at best marginal, well below 1% at the global level (REN21, 2013), and their costs were high compared to other sources of power. They were however beginning to generate considerable enthusiasm. With concern for climate change gaining political ground,[2] renewable energy promotion was on the agenda and support policies for photovoltaics, among other renewable energy technologies, were in place in many European countries. In France, an objective of 5400 MW of installed photovoltaic capacity by 2020 had just been set, and Energy and Environment Minister Jean-Louis Borloo had made photovoltaics the flagship of renewable energy technologies. Solar electricity was included in more and more energy forecasts associated with varying worldviews and policy objectives; on the whole, they predicted significant increases in the use of photovoltaic technologies, even if they expected them to contribute only modestly to electricity production in the medium to long term (International Energy Agency, 2010, 2011; EPIA, 2010, 2011a, 2011b, 2012; PV-TRAC, 2005; Maigne et al., 2008). Prospects were good, but they were prospects: photovoltaic electricity generation was on the rise but only in a few countries (namely Germany, Japan, the US and Spain), and starting from virtually nothing even a rapid increase did not imply massive deployment. It might as well have been a momentary buzz. Still, according to many, the development of photovoltaics on a large scale was bound to happen at some point in the future – but it was not quite happening yet. Or was it?

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[2] Which it was soon going to lose, as a collateral damage of the Copenhagen failure.

In 2010, support policies for photovoltaics were indeed starting to bear fruit. The next few years confirmed the rising trend and, as I will explore in this dissertation, brought new kinds of problems. Installed photovoltaic capacity worldwide has increased from 39 GW in 2010 to 100 GW in 2012, while the costs of photovoltaic modules have decreased by 80% since 2008 (Jäger-Waldau, 2013). The vision of photovoltaics as promising but onerous technologies far from economic maturity no longer holds, or at least needs to be amended: photovoltaics still rely on policy support, but the extent to which they do has considerably reduced, and at any rate their development has gained too much reality to be considered as prospective. Even in France, where it represented 2% of renewable energy production and only 0.8% of electricity production (CGDD, 2014b), it can no longer be totally overlooked. Driven by strong though short-lived incentives, French installed photovoltaic capacity has grown from 69 MW in 2008 to 4.7 GW in December 2013 (CGDD, 2014a), and a small sector has structured which can no longer be completely ignored.

The objective of this dissertation is to contribute to the deployment of a picture of the emergence of photovoltaics as it is happening, and to provide illustrations of how these new entities are dealt with. It started from three puzzling characteristics of photovoltaics. The first, which has somewhat lost relevance, as outlined above, was the discrepancy between the high potential and radiant future envisioned for photovoltaics and their marginal actual contribution to electricity generation.[3] The second one lies in the complex nature of the policy-dependency of emerging photovoltaic markets: they are supported and sustained by policy support, but tend to overflow and disrupt these policies, which have on the whole proven hard to maintain and adjust. The last one has to do with photovoltaic technologies themselves: these are peculiar insofar as they are both research-intensive, high-tech products circulating on a global market and very flexible, modular objects that can be adapted to suit a huge diversity of local contexts and applications. The photovoltaic value chain stretches from the photovoltaic module spot market to local installers, making it challenging to delineate photovoltaics as an object of policy and of research.

Photovoltaics in France

Why then, one might ask, focus on the French case? France is not exactly renowned for its commitment to renewable energy development, and to this day French energy mix and policy remain largely dominated by nuclear (CGDD, 2014b). Contrary to countries like Germany or Denmark, France is not considered to have played a leading role in the early emergence of renewable energy. Whether as a source of electricity, as an industry or as a policy topic, photovoltaics weigh little in France. They have nonetheless evolved in all of these three aspects, and the French case is worth studying in at least three respects.

[3] In 2011, it was estimated that wind, solar, biomass, and geothermal power generation together represented 1.1% of global final energy production (REN 21, 2013). Though the evolution of solar photovoltaics has been exceptional, from a static perspective, their contribution to the global energy mix is marginal indeed, and likely to remain so in the short to medium-term. It is thus the dynamic aspect of the development of photovoltaics, rather than its status at a given moment, that is interesting to study.

The first, most obvious justification for focusing on French photovoltaics is that there has been comparatively little research on the topic so far, with a few notable exceptions (Debourdeau, 2009, 2011a, 2011b; Evrard, 2010; Marcy, 2011). Research on renewable energy development has tended to focus on countries in which renewable energy play a larger part, or on renewable energy with a longer, denser history in France, such as wind power (e.g. Szarka, 2004, 2006, 2007; Nadaï 2007). On top of being marginal in France, photovoltaics have emerged as a market and a political issue only very recently, so it is hardly surprising that research on the topic is also emerging. The sector has undergone rather dramatic evolutions especially in the last five years. These deserve to be documented, especially as they have taken place in a rather chaotic context.

Second, the objective of this empirical focus is not limited to documenting the French perspective. In many respects, the recent evolution of photovoltaic markets and policies in France is similar to the situation in several European countries such as Spain, Italy, Czech Republic, the UK or Germany. Like France, these countries have chosen to rely on feed-in tariffs (FIT)[4] for the promotion of photovoltaic electricity. Though the design of feed-in schemes and the specifics of each situation differ, all of these countries have faced unexpected growth rates in photovoltaic installations that have proven challenging to contain and manage. Feed-in schemes appear hard to steer, and this is not specific to the French case. This dissertation is thus built on the hypothesis that an analysis of the emergence of photovoltaics in France can teach us something about the FIT-supported development of photovoltaics.

Last, the French case is all the more interesting that it is, to an extent, extreme. Photovoltaics seem to rank low as a policy priority, at least insofar as the ambitions regarding photovoltaic electricity generation are modest and the administrative resources devoted to the topic scarce. All the same, in 2009-2010, France boasted the highest incentives for photovoltaics worldwide. This golden era for photovoltaic developers was followed by a brutal backlash when the government found no solution other than the freezing of incentives to stall the unmanageable rise in FIT requests. French photovoltaic policy thus went from an extreme to another in less than a year. Interestingly, the fact that support to photovoltaics was regarded as a peripheral policy is likely to have played a part in making both extremes possible. It can indeed account for the relative carelessness in the initial design and re-adjustment of support schemes as well as for the difficulties in managing them and their effects.

The development of renewable energy in the literature: policies, technologies and project design

This dissertation addresses the development of photovoltaics in France as supported and triggered by feed-in tariff schemes. As a result of this empirical focus, it contributes to an already large, cross-disciplinary and diverse body of literature on renewable energy development and policies. Given its scope, I will not review it extensively in this introduction; instead, I will attempt to outline key approaches and topics of interests.

[4] Feed-in tariffs are State-backed price incentives which guarantee that photovoltaic (or any other type of renewable) electricity is purchased at a tariff above market levels, thereby ensuring the profitability of otherwise non economically viable projects. Their functioning and characteristics will be discussed in details in the following chapters.

Though social science research on renewable energy developed relatively recently – like its object – it spans a vast spectrum of research methods and interests, including economics, sociology, innovation studies and public policy studies. In a simplified and schematic account, the development of renewable energy is addressed from three main thematic perspectives,[5] with some studies combining two or more of them: the analysis of institutions, instruments and policies at play in either their political or their market dimensions; the study of renewable projects design and realisation, with a strong focus on territorial planning and, more recently, on community integration and cooperative projects; and a technology-oriented perspective interested in innovation trajectories, hence in the emergence of renewable energy *technologies*.

The issue of territorial planning and community benefits is not as burning for photovoltaic projects as it can be for other types of renewable energy technologies, chiefly wind power, and I do not address it extensively in this dissertation. It has been addressed by landscape studies (Nadaï & Labussière, 2010; Nadaï, 2012), as well as through the study of community benefits and involvement in renewable energy projects (Walker & Devine-Wright, 2008; Walker et al., 2009), and, more recently, of cooperative renewable energy projects (e.g. Aitken, 2010b; Schreuer & Weismeier-Sammer, 2010).

Issues related to institutions, instrument design and policy effects are probably those that have drawn most attention. They are often addressed considering renewable energy in general, though technology-specific studies are increasingly available as different types of renewable energy sources develop along different paths. A large part of this literature is devoted to the assessment of renewable energy policies in Europe and in European countries.[6] This includes comparisons between various types of renewable electricity support instruments (Timilsina et al., 2012) and in particular between price-based and quantity-based instruments (Hvelplund, 2001; Ménanteau et al., 2003; Lauber, 2004; Midttun & Gautesen, 2006…) as well as analyses and comparisons of distinct national cases (Lipp, 2007; Solangi et al., 2010), among which Denmark (Meyer, 2004), the UK (Mitchell et al., 2006), Sweden (Bergek & Jacobsson, 2010) Spain (Dinica, 2008), and Germany (Frondel et al., 2008; Mitchell et al. 2006). Analyses in terms of support schemes effectiveness and efficiency, both static and dynamic, are particularly numerous. Several studies also consider renewable electricity instruments from an investors' perspective, i.e. in terms of their ability to provide a secure framework for investment and thereby trigger investment in renewable energy technologies (Awerbush, 2000; Dinica, 2006; Couture & Gagnon, 2010; Lüthi & Wüstenhagen, 2012). Attention has also been paid to the institutional aspects of renewable energy policy design. In a policy-oriented perspective, Haas et al. (2004, 2007, 2011) have identified

[5] Given the interdisciplinary character of renewable energy policy research, I have chosen to classify the literature by thematic interests rather than by disciplines. Each of the thematic categories I briefly outline here thus comprises work from a range of disciplines, including but not limited to political science, sociology, geography and economics.

[6] There is also abundant literature assessing renewable electricity support in the US, and especially the effectiveness and efficiency of Renewable Portfolio Standards (RPS) (see for example Barbose et al., 2011; Wiser & Pickle, 1998). However, given the European focus of this dissertation and the considerable differences between renewable energy policy in Europe and in the US, I do not address the US case. Nor do I consider Japanese photovoltaic policy in details. For a comparison between the US and Germany, see for instance Laird & Stefes (2009); for a comparison between the US and Japan, see Shum & Watanabe (2007).

key requirements for the success of renewable energy support, drawing from experience in several European countries. A growing number of these studies focus specifically on the design, effects and relevance of feed-in tariffs for PV-generated electricity, sometimes adopting a rather critical stance (Finon, 2008; Frondel et al., 2008, 2010; Schmalensee, 2012).

In addition to this directly policy relevant literature, many studies have retraced the history and evolution of renewable energy policy in various countries. For instance, Laird (2001) has looked back at the history of renewable energy on the US policy agenda in terms of interests, institutions and ideas from the 1950s to the 1980s, showing how renewable energy advocates failed to gain institutional ground. Evrard (2007, 2010) adopted a similar perspective in comparing the evolution of renewable energy policy in France, Germany and Denmark, insisting on the “mainstreaming” of renewable energy. Marcy (2011) has compared French and German renewable energy policies from an institutional perspective. Lauber & Schenner (2011) have studied the evolution of the debate on the harmonisation of support for renewable energy at the European level, relying mainly on discourse analysis.

As far as technology-specific policies are concerned, the literature is much more abundant on wind power than on photovoltaics, most likely because wind power has been around longer (e.g. Meyer, 1995; Garud & Karnøe, 2003; Nadaï, 2007; Dinica, 2008; Szarka, 2004, 2006, 2007). Germany, being the country with the oldest and most developed photovoltaic support scheme, is also that where the evolution of photovoltaic policies has been most studied. While Jacobsson and Lauber (2006) have documented the early evolutions of feed-in tariffs for PV-generated electricity, Hoppmann et al. (2014) have focused on the series of reforms that they have been through, including most recent ones. As for France, Debourdeau (2009, 2011a, 2011b) has analysed thee marketisation and politicisation of photovoltaics, in particular through the study of feed-in tariffs and their effects, thus stressing the strong interplay between politics and market-making in the emergence of French photovoltaics.

In the Science and Technology Studies literature, there is a growing body of work on the emergence of renewable energy technologies, a lot of which adopts a socio-technical systems or technological innovation systems (TIS) approach (Carlsson & Stankiewicz, 1991; Geels & Kemp, 2007; Bergek et al., 2008). Refining the notion of socio-technical system initially developed by Hughes (1983, 1986), such studies are interested in reproduction, transitions and transformations in socio-technical systems as triggered by technological innovation. They consider the role of actors, networks and institutions in the emergence and diffusion of innovations such as renewable energy technologies. A related field of studies, that of transition management and strategic niche management, focuses on the conditions that enable innovation in renewable energy technologies (or other types of “green” technologies) to develop in “socio-technical niches” and diffuses in “socio-technical regimes”.

In the case of photovoltaics, such analyses have tended to focus on innovation in its early stages and on niche formation, though more recent studies address market diffusion more directly (Dewald & Truffer, 2011). For instance, Verhees et al. (2013) have retraced the development of photovoltaics in the Netherlands, or rather its survival in the absence of significant growth or very supportive policy environments, and discuss the construction by system builders of protective spaces for photovoltaic technologies in unfriendly contexts. Jacobsson et al. (2004) have studied the "German technological system for solar cell" and its history prior to the large-scale diffusion of photovoltaic appliances in Germany. They focus on RD&D programs rather than on market creation policies, but emphasise the role of market formation policies in providing space for maturation and triggering and maintaining learning processes. In the continuity of this work, Dewald & Truffer (2011) have analysed the role of market support in the diffusion of photovoltaics in Germany in recent years and the constitution of distinct end-users market segments, seeking to understand in details the role of market formation processes in the development and stabilisation of TIS. Their study takes into account the variety of photovoltaic applications and market segments, which they identify as an important factor in photovoltaic market growth and learning in Germany. The success of German support policies for photovoltaics, they argue, is rooted in bottom-up policy learning processes.

More economic-oriented research has also considered innovation trajectories in renewable energy technologies, often in relation with support policies. For instance, Schilling & Esmundo (2009) have assessed the cost of support for different renewable energy technologies in the light of its effects on innovation, learning-by-researching and cost reductions. As far as photovoltaics are concerned, Shum & Watanabe (2008) have analysed and compared the learning curves of photovoltaic modules and of balance of systems components,[7] showing that the cost evolution of the later is more context-dependent and harder to track.

Table 1 Overview of the literature on renewable energy support and photovoltaics

Institutions, instruments and policies for renewable energy development	**Technologies and innovation studies**	**Renewable energy projects design and realisation**
Study and assessment of renewable energy policies and instruments *e.g. Ménanteau et al., 2003; Lauber, 2004; Midttun & Gautesen, 2006; Haas et al. 2004, 2007, 2011; Schmalensee, 2012.*	Innovation trajectories and learning curves *e.g. Schilling and Esmundo, 2009; Shum & Watanabe, 2008*	Territorial planning, landscapes *e.g. Aitken, 2010a; Aitken et al., 2008; Nadaï, 2012; Nadaï & Labussière, 2010*
Policy history and evolutions *e.g. Laird, 2001; Evrard, 2010; Lauber & Schenner, 2004; Jacobsson & Lauber, 2006; Hoppmann et al., 2014; Debourdeau, 2011a, 2011b.*	Technical innovation systems, transition studies *e.g. Jacobsson et al., 2004; Verbong & Geels, 2007; Dewald & Truffer, 2011; Verhees et al., 2013*	Community benefits, cooperative projects *e.g. Walker et al., 2009; Walker & Devine-Wright, 2008; Aitken, 2010b, Schreuer & Weismeier-Sammer, 2010.*

[7] The term "balance of system" (BOS) designates the components of a photovoltaic installations that ensure the connection of photovoltaic panels to the electric system and/or grid.

Research objectives and approach

This dissertation shares several interests with the aforementioned literature in all its diversity: it seeks to understand the **emergence** and **development** of a **research-intensive renewable energy technology** and the **policy instruments that support its inclusion in markets**. The originality of the perspective adopted here lies in the attempt to encompass the technological, market and political dimensions of the process studied as equally emergent.

Indeed, though the vast majority of the studies on renewable energy policy explicitly recognize in various ways the interdependence of policy-making, instrument design, market formation and innovation, approaches focused on institutions and technological systems both tend to consider them as distinct processes with relatively stabilised boundaries. In other words, the distinction between what is political, what is economic and what is technological is rarely discussed as problematic in itself.

On the contrary, to study the short period of emergence on which I focus in this dissertation, I adopt an Actor-network theory (ANT) approach and consider these boundaries to be **in flux**: their stabilisation, and hence the delineation of markets, politics and science, is an outcome of market formation policies and processes (Callon, 2009). A key assumption underlying this dissertation is that the specificity of the emergence of photovoltaics as driven by feed-in tariffs lies in its **articulating market devices**, **political steering** and (technological and organisational) **innovation objectives**. In that, it is close to recent STS work seeking to clarify the complex interweaving of **market formation processes** (including the framing of goods and the constitution of economic worth), **innovation** and **formation of political objectives and values** in the case of new markets related to environmental concerns (Callon, 2009; Debourdeau, 2009, 2011a, 2011b; Doganova & Karnøe, 2014; Marres, 2012).

More specifically, this dissertation aims to explore the emergence of grid-connected photovoltaics **as driven by the effects of feed-in tariffs on modular photovoltaic technologies**. In this view, it studies the characteristics of feed-in tariffs as policy and market devices and as political prices, as well as the specificities of photovoltaic technologies. Several research questions related to the object of study itself follow: What distinguishes feed-in tariffs for PV-generated electricity from feed-in tariffs for other sources of renewable electricity, or from other renewable energy support instruments? Can their characteristics account for the turbulence of the emergence of photovoltaics in France? How do feed-in tariffs for PV-generated electricity set people and things in motion, and what kind of activities do they trigger? How are the effects of feed-in tariffs for PV-generated electricity coordinated and regulated?

This primary set of interrogations guides an investigation informed by Actor-network theory that raises further theoretical issues. It unfolds along three main lines.

(1) The ANT approach adopted here first translates into a **commitment to the description of things in-the-making**. Throughout the dissertation, I seek to stay close to the empirical object of study, namely feed-in tariffs for PV-generated electricity, and to follow it in its detours and evolutions almost in real time. From this perspective, I

consider grid-connected photovoltaics and the feed-in tariffs that support it as **emergent entities** whose form is not fully stabilised yet. What are the theoretical and methodological implications of studying objects in flux? How can such objects be defined in a way that conveys their actuality as much as their multiplicity and their emergent character?

(2) This attention to multiplicity then translates into a **focus on effects and events**. Following Gomart (2002), instead of working towards a stable, encompassing definition of what feed-in tariffs for PV-generated electricity *are*, I focus on what they make *happen* and on what *happens to* them. In other words, I do not approach them as instrumental, i.e. as reliable means to a determined end, but as **mediators that spark and frame action**, thereby producing unintended effects. I pay particular attention to the specificities of feed-in tariffs for PV-generated electricity, that is to say to the **coupling of the policy device and of the technology that it targets**. Can this perspective on feed-in tariffs for PV-generated electricity lead to an alternative account of the emergence of grid-connected photovoltaics and of photovoltaic policy in France?

(3) Last, given the somewhat puzzling character of the policy-dependence of photovoltaics, I am interested how feed-in tariffs for PV-generated electricity **frame and support the emergence of a regulated market**. In that respect, feed-in tariffs are political prices supposed to translate political objectives and reflect shared valuations. Subsequently, they raise questions regarding the **intertwinement of politics and markets**, especially as in this case the demarcation between the two is still fluctuating. In particular, they draw attention to the issue of **political tariffs** and to the role of politically constituted objectives, valuations and devices in the construction and operation of markets. Considering them in the light of the intended and unintended effects they produce also brings to the front the **political consequences of market transactions** – an issue that has been raised recently in ANT studies of markets (e.g. Callon, 2007). How are the political and market dimensions of feed-in tariffs for PV-generated electricity articulated? Which theoretical notions are suited to the description of such articulation? What can the study of feed-in tariffs for PV-generated electricity tell us about regulated markets and, more broadly, about processes of market construction and their relations to politics?

Outline

The focus of this dissertation is thus neither on photovoltaic technologies alone nor on feed-in tariffs alone, but on what could be called the *agencement* of feed-in tariffs and photovoltaics. As the following two chapters will detail, I am interested in photovoltaics as modular, emergent technologies deploying on regulated markets framed by feed-in schemes. My analysis mainly relies on actor-network theory, and draws on established ANT concepts on technologies, controversies and matters of concern as well as on more recent ANT developments in the study of markets and politics.

Given the initial commitment, and to an extent the empirical necessity, to study the emergence of photovoltaics in France as it was happening, my theoretical grasp on the subject developed along the way and was refined as the material collected for the case studies enriched my perspective on both feed-in tariffs and photovoltaics. That is why the first two chapters aim to specify all at one time the object of study and the conceptual approach adopted to analyse it. This exploration enables me to define this object as photovoltaics entangled to feed-in tariffs.

Chapter 1 deploys a series of science and technology studies (STS) and ANT concepts and notions to define photovoltaics as emergent and modular technologies. Insofar as they were developed to analyse situations of innovation and controversy, these theories provide me with analytical tools for the study of things in-the-making and of non-stabilised objects such as photovoltaics. In particular, I consider the notions of hybrid forums (Callon, Lascoumes & Barthe, 2001), matters of concern (Latour, 2004, 2005) and issues (Marres, 2005, 2007). In the light of the works of Callon (1998, 2008), Law (2004), Gomart (2002) and Mol (Mol, 1999; de Laet & Mol, 2000), I use ANT's redefinition of action as heterogeneous and relational to characterise photovoltaics as multiple and partially – but partially only – constituted by the arrangements they are entangled into. I thus show that the modularity of photovoltaics implies two things. First, as photovoltaic modules encapsulate a stabilised function (that of generating electricity from sunlight), they can circulate rapidly and on a large scale. In so doing, they can plug into a large diversity of photovoltaic systems, which generates a proliferation in the forms that photovoltaics can take. This makes photovoltaics difficult to delineate as an object of study and justifies the narrowing of the focus on photovoltaics *as they are enacted by feed-in tariffs*.

In order to shed light on the recent proliferation of photovoltaics, **chapter 2** focuses on the feed-in tariffs that have largely contributed to trigger it. Drawing on Callon (2013), I first review the theoretical implications of the notions of sociotechnical *dispositifs* and *agencements*. I then rely on these notions to define feed-in tariffs for PV-generated electricity as political and market *agencements*. ANT perspectives on marketisation (Callon, 1998; Callon et al. 2007; Muniesa & Callon, 2007; Caliskan & Callon, 2009, 2010; Breslau, 2013) and on politicisation (Barry, 2001, 2002; Callon, 2007; de Vries, 2007; Marres, 2005, 2007) are combined to characterise feed-in tariffs as overflowed by design. I thus redefine feed-in tariffs as devices that frame and stabilise the exchange of photovoltaic electricity so as to trigger a process of innovation and experimentation around photovoltaic technologies. Feed-in tariffs are *agencements* that constrain the better to let go, and their success relies upon the balance they strike between control and inventiveness. Their originality stems from the fact that this balance is, in the last instance, calibrated and regulated at a political level: they are political prices caught between the requirements of political legitimacy and acceptability and those of market efficiency. This theoretical apparatus thus enables me to consider them as market but also political *agencements*.

The three chapters that follow are devoted to three case studies that trace photovoltaics entangled to feed-in tariffs in three distinct sites[8] and with different resolutions. They

[8] The term "site" can be understood here in a sense similar to that proposed by Laurent (2011, 2013). For Laurent, the phrase "problematisation sites" ("*sites de problématisation*") refers to the places, arenas and venues where problems related to the "identity of beings and things" ant to their representation are addressed (Laurent, 2013, p. 152). They are "sites of collective investigation and exploration" on a specific topic or issue (Callon, 2012, p. 15). As Laurent points out, the notion makes it possible to describe and analyse in similar terms the diversity of instances that participate to the definition of problematic entities: public participation institutions, electoral representation, technical standardisation organisms, civil mobilisation,

are based on a thorough analysis of relevant documentation (academic literature, legislation and regulatory documents, stakeholders' documentation and website, grey literature, reports from a variety of relevant organisations, etc…), on fieldwork (except for chapter 3) and on a set of 40 in-depth interviews with actors and analysts of the photovoltaic sector (cf. Annex 1).

Chapter 3 traces the history of feed-in tariffs into in Europe, with a focus on how they grew into one of the dominant forms of support for renewable energy and, later, photovoltaic electricity generation. It looks at the evolution of political directions given by the European Union in relation to Member States renewable energy policies, and reviews academic research and expertise on the topic. I start from the apparition of feed-in tariffs in the 1980s as a mean to integrate wind power into existing electricity markets in Denmark and Germany. I then look at their constitution as market *agencements* in the context of the elaboration of European renewable energy policy. Initially meant as a way to contribute to the integration of the internal market for electricity, the development of renewable energy markets in Europe gave way to a process of scale-one experimentation as Member States implemented renewable energy support instruments and a "network of experimentation" emerged (Callon, 2009) in the 2000s. During this process, which was steered and documented by EU institutions, renewable energy support instruments were refined and sophisticated. Instruments and theories about these instruments evolved jointly, making it hard to distinguish between "cook and recipe" (Holm & Nielsen, 2007). Feed-in tariffs emerged as a dominant form of support for renewable energy until the turbulences entailed by the rapid deployment of photovoltaics called them into questions.

Chapter 4 shifts the focus on the French case. It studies how the marketisation of photovoltaic electricity in France eventually led to its brutal politicisation and its tentative articulation as an issue. The first section retraces the history of photovoltaic policy in France, and in particular the introduction of feed-in tariffs for PV-generated electricity between 2000 and 2013. In this section, I analyse the market *agencements* that the successive reforms of the scheme set up. The second section is centred on the actual effects of these feed-in tariffs, and specifically on the way support went off-track between 2008 and 2011. I focus on the moratorium and consultation on feed-in tariffs that took place between December 2010 and March 2011, which I describe as a political moment as defined by Barry (2001, 2004), that is as the opening of new spaces of disagreement. I show how the uncontrolled inflation of the photovoltaic sector and the overflows that ensued led the government to freeze the incentive system and to re-open it as a political issue (Marres, 2007). I try to convey the dramatic and disorderly character of this process and stress how it enabled the photovoltaic sector to constitute as a public and a group of political – not just economic – actors. However, it ended with an attempt toward depoliticisation through the reformulation of feed-in tariffs, with mitigated success. This highlights the role of calibration as much as the difficulty – if not impossibility – to fully master the effects mediated by feed-in tariffs.

Chapter 5 is also interested in the ways feed-in tariffs set people and things in motion. It adopts a perspective influenced by STS studies on innovation and entrepreneurship as processes of collective experimentation (Akrich et al., 2002; Doganova, 2009; Garud &

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etc... (Laurent, 2013). The three sites I explore in this dissertations thus provide distinct areas for the exploration of the making of policy-supported grid-connected photovoltaics.

Karnøe, 2003). It focuses on a mutualised photovoltaic project carried out by an agricultural cooperative in the Lot (Midi-Pyrénées) from 2008 to 2010. On top of its scale, what makes this project original is the way the cooperative seized the feed-in tariff at its peak and turned it into a collective opportunity and a resource for territorial development. The tariff provided high investment security; combined to the possibilities provided by the modularity of photovoltaics, it triggered the interest of the cooperative and equipped it to constitute itself as a territorial actor in the energy sector. By retracing the trials and reformatting that were necessary to carry out the project, the chapter shows that the conversion of the tariff opportunity into a resource cannot be taken for granted. Only at the outcome of a risky adventure, and after having enrolled several partners can the photovoltaic-equipped cooperative come out as a player on renewable energy markets and, to an extent, the promoter of a political innovation.

Chapter 1

Introducing photovoltaics as emergent and modular technologies

"O chestnut-tree, great-rooted blossomer,
Are you the leaf, the blossom or the bole?
O body swayed to music, O brightening glance,
How can we know the dancer from the dance?"
W. B. Yeats – *Among School Children*

What does it mean to study the recent emergence of photovoltaics in France? What makes it different from that of other renewable energy technologies? In other words, how can photovoltaics be characterised as an object of study? And what does it imply to focus on its recent evolutions and to qualify it as "emergent"? The objective of this chapter is to define photovoltaics along with the analytical tools and concepts that can help grasp its specificities for the purpose of this dissertation.

Defining photovoltaics, it turns out, is not as trivial as it may seem. The term "photovoltaic" is an adjective that qualifies things "relating to the production of electric current at the junction of two substances exposed to light" (Oxford Dictionary). It can then refer to specific processes, to technologies operating according to such processes, or to the nature of the electricity so generated. "Photovoltaic" then designates an effect and, by extension, the various means through which it is performed, rather than a clearly demarcated set of technologies. Interestingly, as a noun, "photovoltaics" only exists in plural form to designate either "the branch of technology concerned with the production of electric current at the junction of two substances" or the "devices having such a function" (Oxford Dictionary).

The core principle of photovoltaics is stabilised: the photovoltaic effect was discovered by Becquerel in the late 19th century, and the first silicon photovoltaic module was developed by the Bell Laboratories in 1955. Photovoltaic technologies have been around for several decades, but new applications have emerged recently. Over the last fifteen to twenty years, grid-connected photovoltaic appliances have indeed developed as a way to produce renewable energy. Photovoltaics as a source of renewable energy has sparked enthusiasm and activity, leading to rapid transformations in photovoltaic technologies, in their markets and in the stakes associated to their deployment.

This dissertation does not consider photovoltaics in general, but focuses on the new grid-connected applications that have spread in recent years. It is interested in the innovative and emergent dimensions of grid-connected photovoltaics. In this perspective, I highlight three specificities of the recent deployment of photovoltaics that, as I will explore in this chapter, also constitute analytical challenges. First, the kind of photovoltaics I am interested in is not stabilised: it is **emergent, multiple, and evolving**. Second, partly as a consequence of its emergent character, "photovoltaics" refers not only to a set of electricity-generating technologies, but also to **the booming markets, new collectives and emerging political issues that constitute around them**. Last, photovoltaic technologies are **modular**: they can circulate widely and be combined in many ways and at many scales while retaining a stabilised function (that of generating electricity from light). This last characteristic adds to the diversity that the term "photovoltaics" covers, while it also influences the development of photovoltaic applications.

To capture the specificities of photovoltaics as a set of technologies, markets and political issues and to tackle the analytical challenges they pose, I rely on tools developed by science and technology studies (STS) and in particular by actor-network theory (ANT). In this chapter, I review a series of STS and ANT concepts and show how they can help **address photovoltaics as emergent and modular**. STS are indeed specialised in the study of innovations, controversies and non stabilised objects; they are also well-equipped to analyse the material aspects of technologies.

This chapter starts with an overview of the recent transformations of the photovoltaic sector. This allows me to define the emergent character of photovoltaics in more details and to stress the difficulties encountered when addressing it in real time. I then review STS approaches to things in-the-making in order to frame my approach to the emergence of photovoltaics as an object of research. The second half of the chapter constitutes an attempt at qualifying photovoltaic technologies as active players in their own deployment. I focus on ANT and particularly on its redefinition of action and objects. Because it is particularly attentive to the heterogeneity and multiplicity of *actants*, ANT enables me to shed a new light on the modularity of photovoltaics, which will be further developed in the next chapter.

Section 1 – Documenting the emergence of grid-connected photovoltaics

1.1. "*In medias res*"

One key difficulty when studying the *emergence* of photovoltaics was that it implied studying a process as it was unfolding. Photovoltaics have changed very fast over the past decade, and still change much from one year to the next. In France, until the late 2000s, grid-connected photovoltaics were at best marginal: not only did they exist mainly as a promise, a more or less well-defined potential, maybe a project; even as such, they were marginal – negligible for some. They are now the dominant form of the technology and, although the deployment of grid-connected photovoltaics is not exactly a foreground issue, it has become a matter of public concern. It has taken forms and has had actual, concrete consequences that were not envisioned ten years ago. There are two aspects to this evolution: first, photovoltaics **have emerged extremely fast**, and photovoltaic markets have expanded exponentially; second, this emergence has not been without turbulences, and is in fact characterised by **strong tensions and deep uncertainties**.

1.1.1. An extremely fast-emerging technology

1.1.1.1. The rise of grid-connected photovoltaics

The photovoltaic sector has changed thoroughly in just a few years. In many respects, the period stretching from 2008 to 2012 was a turning point, and 2010 a pivotal year. These changes had been building up throughout the 2000s. They were driven by policy support explicitly aimed at opening markets for grid-connected photovoltaics.

Support to grid-connected photovoltaics emerged in the 1990s in Germany and Japan, where photovoltaic installation programmes such as the German 1,000 and 100,000 solar roofs programme or the Japanese long term strategy (1994) sparked the growth of new markets for photovoltaics. Prior to that, photovoltaics deployed on a niche market disconnected from mass electricity markets. It was mainly used in "communication, industrial and stand-alone systems" (Jäger-Waldau, 2013, p. 45) and was therefore not used as a potentially large-scale electricity generation technology able to feed the grid. Support schemes for photovoltaic technologies and electricity spread, developed and sophisticated widely during the 2000s, especially in Europe, pushing market growth in an increasing number of countries.

The development of support for grid-connected photovoltaics proposed an alternative configuration of the technology, framing it as a source of green electricity that could potentially become competitive on the electricity market (which it was not previously, except as a project or, its detractors would say, an utopia). It also triggered an unprecedented expansion, with the effect that "since 1990, PV production has increased by almost three magnitudes, from 46 M to about 38.5 GW in 2012." (Jäger-Waldau, 2013, p. 45). Indeed, as of 2013, "solar PV is starting to play a substantial role in electricity generation in some countries, meeting an estimated 5.6% of national electricity demand in Italy and about 5% in Germany in 2012, with far higher shares in both countries during sunny months" (REN21, 2013, p. 47).

Though enthusiasm has stifled over the last couple of years, investments in solar energy remain high and account for more than half of all new renewable energy investments (Jäger-Waldau, 2013). This expansion has not affected off-grid applications, or barely so; photovoltaics have thus changed face completely, as their main application twenty years ago has now become marginal. Indeed, "the vast majority of PV capacity today is grid-connected, with off-grid accounting for an estimated 1% of the market, down from more than 90% two decades ago" (REN21, 2013, p. 46).

1.1.1.2. An overview of current photovoltaic markets

There are two sides to photovoltaic markets: the production of photovoltaic cells, modules and panels, which is now a global industry, and the production of photovoltaic electricity. Both have been growing exponentially, though they have also to an extent grown increasingly apart.

Photovoltaic installation and electricity generation remain largely dominated by a few European countries, with Germany far ahead. If one considers only the time span during which the research for this dissertation took place (i.e. 2010-2014), cumulative installed capacity worldwide grew from 39 GW in 2010 to 79 GW in 2011 to 100 GW in 2012. Europe, where "since 2000, solar PV electricity generation capacity has increased 373 times" (Jäger-Waldau, 2013, p. 11-12), has consistently accounted for around 70% of these installations, though its share has decreased to about 57% in 2012 (REN21, 2013, p. 44).

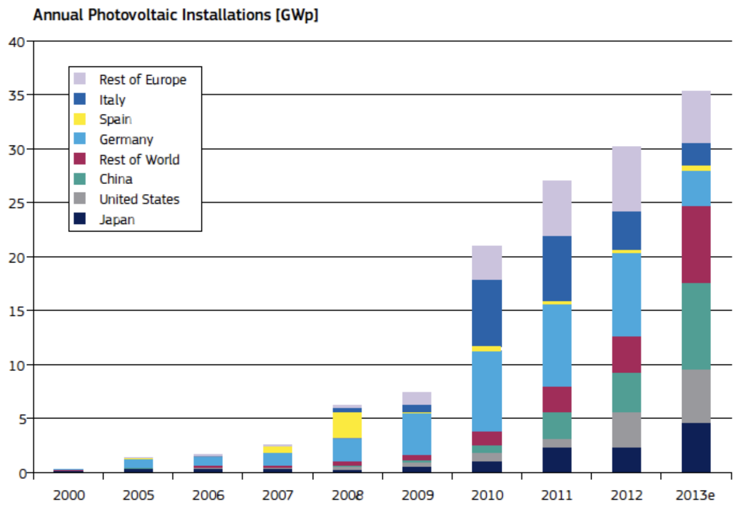

Figure 1 Annual photovoltaic installations from 2000 to 2013 (Jäger-Waldau, 2013, p. 10)

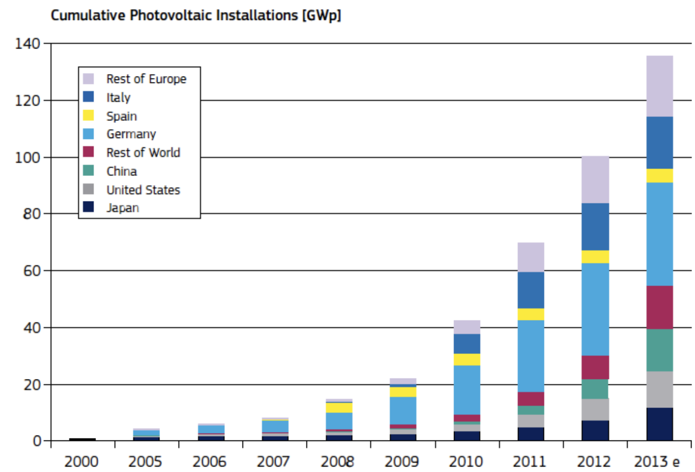

Figure 2 Cumulative photovoltaic installations from 2000 to 2013 (Jäger-Waldau, 2013, p. 11)

On the other hand, the centre of gravity of the photovoltaic module production industry has clearly shifted to China, which together with Taiwan now accounts for more than 70% of worldwide production (Jäger-Waldau, 2013, p. 8). As the REN21 report (2013) sums up, “over the last decade leadership in module production has shifted from the United States, to Japan, to Europe, to Asia” (REN21, 2013, p. 47). China has indeed proven quite aggressive in developing industrial capacities, especially in 2010 and 2011; this build-up of massive module production capacities has resulted in excess production, driving already decreasing costs down even faster (REN21, 2013, p. 47). As a result of this overcapacity, “since 2008, PV module prices have decreased by 80%, and by 20% in 2012 alone” (Jäger-Waldau, 2013, p. 8).[9]

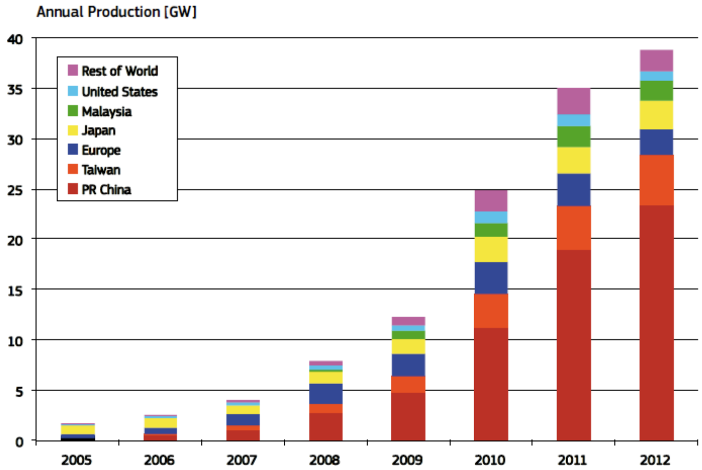

Figure 3 World photovoltaic cell/module production from 2005 to 2012 (Jäger-Waldau, 2013, p. 7)

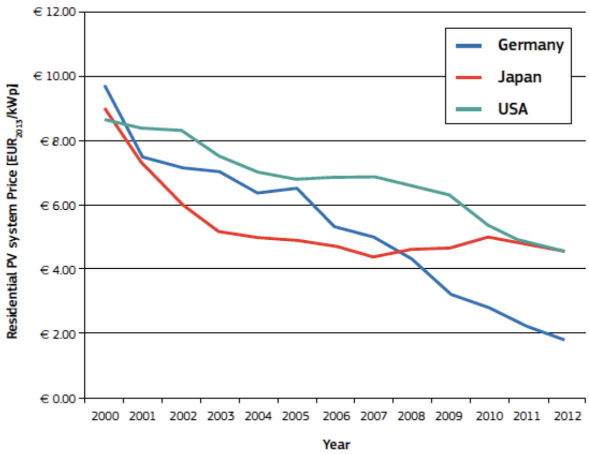

Figure 4 Residential photovoltaic system price development over the last decade (Jäger-Waldau, 2013, p. 27)

[9] These sharp price decreases have been constantly analysed as dramatic since 2008. Here is how the JRC described the situation in 2011: “The change of market from a supply restricted to a demand-driven market, and the build-up overcapacity for solar modules, has resulted in a dramatic price reduction of more than 50% over the last 3 years” (JRC, 2011, p. 10).

In many respects, 2010 was a pivotal year. It saw a doubling in installed capacity as well as the opening of large manufacturing capacities in China and, as a result of these two evolutions, can be considered the year when photovoltaics changed scale. Costs were going down, support policies were still at full blast (except in Spain), and enthusiasm was up: photovoltaics were happening. In France, too, 2010 constituted a turning point. The French market, driven by the feed-in tariffs set up in 2006, bloomed between 2008 and 2009, and grew out of proportions in 2010, leading up to a political turnaround in December of that year. Between 2008 and 2012, photovoltaics turned from a promise into a problem: by spreading more widely, it brought along new, unexpected issues.

1.1.2. Tensions, turbulences and uncertainties

Such a rapid emergence is necessarily more turbulent than any graph can tell. As it gained ground, photovoltaics as a technology, a market and an issue has been through successive reconfigurations. Though most analysts maintain that the fundamentals remain good and that photovoltaics will continue to expand in the long run, the sector is currently characterised by tension and uncertainty (Jäger-Waldau, 2013).

The rapid development of the sector in itself is a major source of instability. Additional turbulence stems from the tensions between the dynamics of module production and these of photovoltaic systems installation. While they are closely related and interdependent, module production and system installation constitute two distinct markets that rely on very different actors, factors and logics. Module production, dominated by Chinese firms, is a highly competitive, industrial market of global scale; system installation, on the other hand, is much more diverse and diffuse, and largely dependent on factors that vary widely from one country to the next (support policies, administrative constraints, investment frameworks, etc…). Both of them have proven extremely tense and unstable recently, the uncertainties of each exacerbating those of the other.

The market for photovoltaic modules is extremely competitive, and all firms in the sector are "under enormous pressure" due to rapidly declining prices and current overcapacity (Jäger-Waldau, 2013, p. 8). In the last five years, some of the top players (such as the German company Q-cells) have gone bankrupt as the market shifted to Asia. In such a highly competitive environment, data is hard to consolidate and forecasts are rather uncertain. Because photovoltaic module production is such an unstable and competitive market, variations in module prices have recently been surprising, if not utterly unpredictable.

Photovoltaics are generally considered to follow a standard learning curve, "with an average learning rate of 80%, i.e. the average selling price (ASP) of solar modules decreased by 20% for each doubling of production volume" (Jäger-Waldau, 2013, p. 25). Yet, though the learning curve does remain a good trend indicator, punctual fluctuations mean that prices do not follow it steadily, making their short-term evolution hard to forecast with precision. The sharp decrease that started in 2008 was rendered all the more surprising that prices had remained stable during the four previous years, as the JRC *PV status report* for 2013 noted:

"It is interesting to note that between 2004 and the second half of 2008 the price of PV modules remained pretty constant at between 4 and 4.5 USD_{2012}/Wp. This happened despite the fact that manufacturing technologies continuously improved and companies significantly scaled up production. The reason was the expanding markets in Germany and Spain, where the FiTs enabled projects developers to be profitable at that price, coupled with the temporary shortage of polysilicon between 2004 and 2009, which limited silicon production and prevented effective pricing competition […]" (Jäger-Waldau, 2013, p. 25).

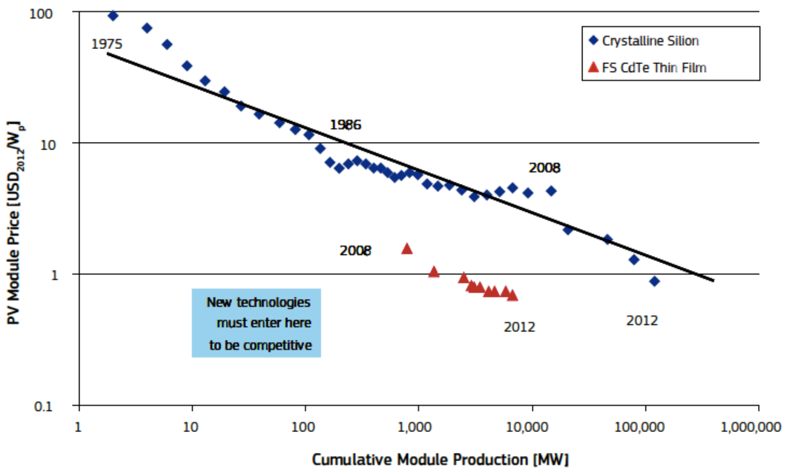

Fig. 6: Price-experience curve for solar modules (data source: Bloomberg New Energy Finance and PV News)

Figure 5 Price-experience curve for solar modules (Jäger-Waldau, 2013, p. 25)

While the policy-driven increase in photovoltaic installations had impacts on the module manufacturing industry, the drop in module prices has largely contributed to the disruption of support schemes. Indeed, another major source of uncertainty in current photovoltaic markets has been the instability of support policies. Support for photovoltaics developed during the late 2000s, when feed-in tariffs became a dominant form of support. However, such policies fell short of aligning to the rapid market evolutions that triggered sharp decline in prices. As this dissertation will explore, the discrepancy between the pace of policy adjustments and the pace of the decline in the price of photovoltaics has led to rather hectic reforms and to widespread policy instability.

While photovoltaic installation markets remain policy-dependent, this political volatility makes it even harder to forecast short-term evolutions, leaving the sector straddled between prospects of future growth and a current climate of low investor confidence. Thus, "the continuation of the difficult financial situation worldwide and the fact that support schemes are changed with a short-term notice, which reduces long-term investor confidence, mean that risk premiums are added and project financing is made more difficult. On the other hand, the declining module and system prices have already opened up new markets, offering the prospect of further growth of the industry – at least for those companies with the capability to expand and reduce their costs at the same time" (Jäger-Waldau, 2013, p. 8).

This broad overview gives an idea of the proliferation that has characterised photovoltaics recently. Behind those aggregated figures and trends, one can only imagine the diversity of innovations, transformations and crises that occurred and that were not always easy to detect and track, since they were just happening. Though it still accounts for a very marginal share of electricity production, photovoltaics have clearly changed scale and can now be considered as an emerging source of electricity. Saying this does not imply that it will rise to prominence or will necessarily fulfil its potential; rather, it emphasises the transformations that photovoltaics are currently undergoing and the deep uncertainties as to what they will lead to. It stresses that something is happening to photovoltaics and that, as of now, there is no telling exactly what this something will be. The recent developments of photovoltaics thus suggest that it is emergent, in the sense that it is coming together as a specific technology, market and issue from the combination of heterogeneous, independent elements whose co-evolution is unpredictable.

1.1.3. Following the evolutions of photovoltaics in real time

Many of these developments – indeed, most of them – occurred while the research presented in this thesis was conducted. As a result, what surprised those involved in the emergence of photovoltaics in France between 2010 and 2014 surprised me just as much. It follows that this dissertation documents the emergence of photovoltaics as a technology, a market and an issue in almost real time,[10] with all the limitations and discomforts that such a position implies: lack of perspective, uncertainty as to what will come to matter and what will turn out to have been little more than noise, difficult access to key players who can be hard to identify, profusion of documents and traces but quasi-absence of analyses that could help navigating them, the risk of looking in the wrong direction and missing something crucial… When I started my research, photovoltaics was only just emerging in France and it still seemed uncertain whether it was here to stay.

In other words, this position implied studying a new-coming object in the thick of it, and so being confronted with the messiness, the unprecedented character and the irreducible uncertainty of emergence. As such, it also provided a rare richness: that of allowing access to things-in-the-making, to all that comes into play before an object, an issue, a group, a fact cools down and solidifies. It meant being exposed to all that gets lost as things quiet down because it is not, or cannot, be archived and documented: emotions, errors, mis-readings, uncertainties, fleeting identities, short-sightedness (Law, 2004)… All of these elements disappear when a situation stabilises, indeed have to disappear for a situation to stabilise (even if they can always re-appear and situations may always, at least in principle, destabilise).

From such a perspective, it becomes easier to "treat with the uncertainties and undecidabilities of process as well as with means and ends" (Law, 2004, p. 152). Since the researcher is confronted to the same "uncertainties and undecidabilities" as the

[10] The "almost" is important, since there is in fact a lag between the actual events and my study of them; however, except in the case of Fermes de Figeac (chapter 5), this lag did not reduce uncertainties much.

actors and is not more able to reduce them, the existence of these unknowns has to be addressed and at least accounted for. One way of doing so is to embrace them as data in and for themselves, that is as a constituent part of the matter under study that cannot be disentangled from it. From this standpoint, the unstable and emerging character of photovoltaics may be a methodological challenge, but it is not an obstacle.

The research presented in this dissertation thus started *in medias res* (Latour, 2005, p. 123), when photovoltaics was starting to fulfil its promises but also to turn into an issue. It ends *in medias res* as well, since the problems that were emerging around photovoltaics when it started have not necessarily been solved: its object is not fully stabilised. The point of this dissertation is then to **trace the displacements and transformations of photovoltaics in France in the late 2000s and early 2010s** as they appear to someone who started studying the topic in 2010.

How, then, to give account of an ongoing process? What does it imply to study an emerging object, and to what extent can photovoltaics be qualified as emergent?

As it specialises in the description of controversies, processes as they unfold and things in-the-making, actor-network theory provides a series of useful tools to face the challenges of research *in medias res.* With photovoltaics, I encountered three main difficulties owing to this positioning, which ANT helped me formulate.

The first one, already outlined in the previous pages, has to do with **the implications of studying things as processes** and the tension between stability and instability, homogeneity/unity and heterogeneity/multiplicity. The second one pertains to the **heterogeneous and contested character** of photovoltaics: they are new technologies as much as emerging markets and public issues, but, whichever way it is addressed, they are problematic. It is thus difficult if not impossible to isolate one dimension of photovoltaics that could be researched independently; on the contrary, heterogeneous actors, issues and perspectives tend to proliferate as much as solar panels do. This is where the tools and methods that STS and especially actor-network theorists developed for the study of controversies and heterogeneous assemblages come in handy.

One last difficulty, related to the other two but perhaps more deeply rooted, stemmed from my difficulty to **grasp photovoltaics and delineate them as a specific, well-defined entities**. This might seem puzzling at first – photovoltaics could be defined in a rather straightforward manner devices that convert sunlight into electricity. Yet, writing this says nothing of the many combinations and adjustments required to actually convert sunlight into electricity, of their heterogeneity or of their multiple possible combinations.

1.2. Contested objects in-the-making

1.2.1. The study of "things-in-the-making"

One distinctive feature of STS is their focus on things in-the-making. STS have evolved into a relatively large and diverse field of research, but they are overall more interested in processes than in results. Rather, they are interested in how results become results, in how outcomes are achieved, stabilised and/or challenged. From an STS perspective, stability and homogeneity are what needs to be explained: they are never given, always-already-there, but are instead constructed and performed through practices that are both material and discursive.

From this attention to processes and practices, a set of shared methodological guidelines follows. The first one is the commitment to ***symmetry***, which was formalised early on in the history of the field (Bloor, 1976 as cited in Law, 2004). Its rationale is that to give a fair account of a process, one cannot take its outcome for granted. As a result, true knowledge and false knowledge, successes and failures have to be explained in the same ways and in similar terms (Law, 2004, pp. 101-103). Truth, efficiency or profitability are considered as results. As such, they carry no explanatory value but instead are what requires explanation (Akrich, 1989; Callon, 2006).

Especially when doubled with the attention to practices, this leads science and technology students to ***open black boxes*** (Pinch, 1992). Indeed, it implies investigating the (often long, uncertain and non linear) work that is necessary to stabilise knowledge, technologies, systems, procedures, etc... Whether this work will succeed or fail is never known for sure in advance. STS have demonstrated how costly and difficult this work can be, but they have also shown how easily these efforts and the vast numbers of people and things involved are forgotten once outcomes stabilise and become unproblematic.

This assumption that things or categories are never self-explanatory but always *made* then translates into an interest in the ***diversity and heterogeneity*** of the practices and entities involved in the process. First (and this owes to the fact that STS were initially concerned with the making of scientific knowledge), knowledge and action are not conceived of as distinct realms, but rather as co-participants in the outcomes of such processes. In line with the symmetry principle, STS do not rank forms of knowledge as more or less legitimate, this ranking itself being a specific outcome of the processes studied. Last, STS are attentive to the variety of actors and entities involved in the production of knowledge and technology: non-human actors are granted the same status as human actors; materiality is deemed crucial and cannot be eluded.

When adopting such an approach, it is then necessary to artificially re-create a form of agnosticism, that is **a perspective from which the outcome of the process studied does not interfere with the study of the process**. This is one of the key challenges faced by STS, especially as they historically have dealt with particularly "hard stuff": scientific facts, technologies, economic markets…

Indeed, the interest of STS lies precisely in their studying *how* (i.e. through which specific processes, practices and assemblages) "hard stuff" solidifies – or fails to solidify and dissolves. In principle, this implies that anything that is stable, unproblematic and not questioned has not always been so and that one does not have to consider it as something "already made" but can instead study the process of its making. Such processes are not always visible. In fact, when they succeed they become invisible, and this was one of the crucial points made by Latour and Woolgar in *Laboratory Life* (Latour and Woolgar, 1986).[11]

[11] As John Law recalls, in their ethnography of the Salk Institute, Latour and Woolgar show that realities, statements about those realities and the instrumental, technical and human

As a result, STS usually focus on these moments during which things are being made or un-made: accidents, crises, innovation, controversies… Following or retracing how these events unfold, they strive to reconstitute how matters are closed and/or re-opened. In the case of photovoltaics, not much effort needs to be put into reconstituting such a situation, since it currently remains an unsettled issue. Nevertheless, it is important to acknowledge that at no point is everything unstable: the point of STS is rather to account for the tension between stability and instability and for all the work and energy that are necessary to achieve and maintain closure.

1.2.2. Controversies as processes of collective exploration and problematisation

STS have thus reconstituted experiments in-the-making (Shapin and Schaffer, 1985; Collins, 1975; Latour and Woolgar, 1986), the detours of specific technological innovations (Akrich, 1989; Latour, 1992) or the emergence of vast socio-technical systems (Hughes, 1983). But one of their most fertile fields of investigation has been the **analysis of technological and scientific controversies**.

In situations of controversy, the contested matter is deployed and all its ramifications are made apparent. Since boundaries, facts, interests and legitimacies are questioned, controversies reveal the negotiations through which technical choices and scientific facts are established (Callon, 2006). Such moments thus provide a particularly rich picture of technical or scientific issues, and one that can only be described symmetrically: as soon as symmetry is lost, the controversy is closed, hence lost too. As Callon, Lascoumes and Barthe put it, controversies are collective explorations:

> "to start with controversies helps to reveal events that were initially isolated and difficult to see, because they bring forward groups that consider themselves involved by the overflows that they help to identify. […] The controversy carries out an inventory of the situation that aims less at establishing the truth of the facts than at making the situation intelligible. […] [This inventory] is carried out at the same time as the actors arrive on the scene. The distribution is not known in advance but is revealed as the controversy develops, and it is precisely for this reason that the latter is an apparatus of exploration that makes possible the discovery of what and who makes up society." (Callon et al., 2001, p. 28)

It follows that controversies constitute a form of laboratory for STS: they are relatively **well-identified moments during which the ramifications of a given problem are made visible, debated and ordered**. Socio-technical controversies have the power "to reveal the multiplicity of stakes associated with one issue, but also to make the networks of problems it raises both visible and debatable" (Callon et al., 2001, p. 31).

An additional advantage of the study of controversies is that it makes it possible to consider the articulation of the problem and the constitution of the group that is relevant to address it as co-produced in a single movement (Callon et al., 2001; Marres, 2007) While the controversy rages, it is not possible to draw a clear line between the

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configurations and practices that allow these statements to be made are all produced together, but, once statements are agreed upon, "the largest part of the work which has gone into their production is deleted" (Law, 2004, p. 36).

technical, the natural and the social, between knowledge production and decision making; the production and stabilisation of boundaries is precisely what is at stake, and it is one of the outcomes of closure.

1.2.3. Rendering the co-articulation of objects and of the assemblies concerned by them: hybrid forums, matters of concerns, and the publicisation of issues

STS scholars have used several concepts to analyse these moments when one witnesses "the association between knowledge controversies and the emergence of new publics" (Whatmore & Landström, 2011, p. 583).

Callon, Lascoumes and Barthe (2001) have coined the notion of "***hybrid forum***" to give account of the heterogeneous collectives comprising both humans and non-humans that emerge and structure when techno-scientific controversies arise. These correspond to the more or less formal arenas that are articulated along with the topic of controversy and that "host deliberative processes in which heterogeneous actors – those belonging to affected groups, experts, politicians and officials – collectively define the problems in which they are all implicated (Callon et al., 2001, pp. 36, 167-68)" (Marres, 2007, p. 762).

To trace similar events, Latour talks of "***matters of concern***", which he opposes to stabilised, undisputed "matters of fact" and defines as "highly uncertain and loudly disputed", "real, objective, atypical and, above all, *interesting* agencies" that "are taken not exactly as objects but rather as *gathering*s" (Latour, 2005, p. 114). The study of matters of concern translates into a commitment to deploy things and to be attentive to their multiplicity. As Latour writes, "it is the thing itself that has been allowed to be deployed as multiple and thus allowed to be grasped through different viewpoints, before being possibly unified in some later stage depending on the abilities of the collective to unify them" (Latour, 2005, p. 116). It follows that the study of controversies is not limited to a mapping of different viewpoints about a single, already unified object. Instead, it considers the object as constituted and stabilised over the course of the controversy.

Latour's use of the apparently trivial word "**things**" is in fact very specific. Drawing on Heidegger's reflections on the etymology of the words used for "things" in European languages and on his conception of things as gatherings, Latour understands "thing" as a word that can **refer to both objects and assemblies** and that is thus able to capture the **tension between the unity of a stabilised object and the multiplicity of what needs to be put at work to constitute it**, that is the tension between homogeneity and heterogeneity.

> "A thing is," he writes, "in one sense, and object out there, and, in another sense, an issue very much in there, at any rate, a gathering. To use the term I introduced earlier now more precisely, the same word thing designates matters of fact and matters of concern" (Latour, 2004, p. 233).

The notions of "hybrid forums" and "matters of concern" then imply that **what is disputed cannot be considered without also looking at what and who is involved in disputing it.** The matter under consideration and the organisation of its consideration are seen as articulated in the same movement.

The notion of "hybrid forum" does not simply describe an arena equipped with deliberative procedures to accommodate heterogeneous actors; rather, it characterises the **collective operation of articulating *both* a controversy *and* the assembly of those concerned by it, as well as the resulting ordering of knowledge and expertise about it-and-them**. It stresses that the arena does not pre-exist the controversy, or that it is at least transformed, displaced by it.

Though slightly more general in scope, the notion of "matters of concern" produces the same methodological effect of preventing the premature separation of the object and the assembly. These are, at least for a spell, the same *thing*, and it is only once the matter has been settled into a matter of fact that it can be disentangled from the assembly (now completely folded in it) that participated in its constituting. As Latour writes,

> "Things have become Things again, objects have reentered the arena, the Thing, in which they have to be gathered first in order to exist later as what *stands apart*" (Latour, 2004, p. 236).

Marres has drawn on these notions to develop an approach to "public involvement in politics as a practice that is occasioned by issues and dedicated to their articulation" (Marres, 2007, p. 775). According to her, in spite of dissolving "the customary separation between the epistemic process of knowledge formation and political processes of community opinion, consensus, decision and policy formation" (Marres, 2007, p. 762), STS approaches have tended to reproduce procedural accounts of public involvement in politics. Combining an STS perspective to the works of Dewey and Lippman on publics, she develops an approach centred on **public involvement as a practice of issue articulation**: publics emerge when existing institutions and procedures fail to address a specific issue, and they become publics by articulating issues. She thus extends the scope of the study of "matters of concern" to that of their gradual political articulation, which, she stresses, cannot be taken for granted and has to be described and accounted for as a practice.[12]

1.2.4. Gathering photovoltaics

Following this theoretical line, this dissertation is interested in the various ways in which photovoltaics is gathered. It studies various attempts to assemble it and how they have fared. Not all three case studies have deployed as controversies, but what is certain is that, while my research was carried out, photovoltaics in France *was* a controversial topic. The three cases studied here also share a common feature: they can all be deployed so as to **highlight the heterogeneity of the gatherings that strive to make photovoltaics stand**. The point, then, is not to extract from the case studies a unified, substantial definition of photovoltaics as a stable, distinct object. Instead, I am interested in how photovoltaics are displaced; in how they change shape and size and take part in various associations that are put at trial; in how they move from being promising innovations to being products trying to define their markets to being political problems and then back again to being innovations whose potential has been reconsidered, and more often than not are several of these things, and more, at once.

[12] I will come back to Marres's argument and develop it more thoroughly in chapter 2

That is not to say that all about photovoltaics are completely fluid, unstable, constantly shifting; if they were, there would be no photovoltaic systems at all, or at least they would not be unified enough to be constituted as an object of study. The core function of photovoltaic technologies, for example, is not contested: "photovoltaics" refers to the various technologies that use the photovoltaic principle to convert the energy of solar radiations into electricity, and to the electricity thus generated. The fact that a large and diverse range of technologies can perform this function and that they can be arranged in many ways to do so is not contested either.

Interestingly, these stable features tend to constitute photovoltaics as miltiple. Photovoltaics, in fact, are defined by the performance of a function. Photovoltaic technologies have developed into modular technologies, that is to say into technologies that encapsulate this function and can be displaced and combined in many ways without their performance being altered. Indeed, they are composed of independent photovoltaic modules connected and combined together; modules are easily displaced and only need to be plugged in to work. Studying in details what made photovoltaics modular is beyond the scope of this dissertation.[13] This makes the issue of how to account for the thing-as-gathering even more prominent, and may lead to a new problematisation of it.

If one salient characteristic of photovoltaics is their modularity, that is, their capacity to be easily arranged in many ways and at different scales while retaining their core functions (which does not mean that they cannot also take on other functions), then how should they be approached as an object of inquiry?

This questioning, only roughly formulated at this stage, cuts across the whole dissertation. Throughout the case studies, the tension between stability and destabilisation, framings and overflows, unity and multiplicity is a pivotal issue, and I suggest the modular quality of photovoltaics gives it a distinct twist. Looking more closely into ANT conceptions of agency and actors may provide clues as to how to approach this characteristic of photovoltaics.

[13] I address this issue in more details in the second section of this chapter.

Section 2 – An ANT perspective on the modularity of photovoltaics

2.1. The ontology of Actor-Network theory

Because it questions the composition of photovoltaics as collective and heterogeneous entities that can take diverse forms according to how they are combined, the approach adopted in this dissertation hinges on some of the core specificities of actor-network theory. These deserve elaboration here, as does my interpretation of them.

Actor-network theory can be summarised as a very literal interpretation of the commitment to study "things-in-the-making". Its proposition is that **sticking to strict but thorough description** may prove more fruitful than attempts at explanation (Latour, 2005). How far can we follow actors? How much of an object can be unfolded and deployed?

It follows that, despite its name, ANT is not a theory so much as a method, or, perhaps more radically, a toolbox for description. Its key guideline is to follow actors as far as possible, and to reject any form of exogenous or contextual explanation. Indeed, its "main tenet is that actors themselves make everything, including their own frames, their own theories, their own contexts, their own metaphysics, even their own ontologies" (Latour, 2005, p. 147). Anything that intervenes leaves traces; anything that leaves traces is part of the actors (or, as actor-network theorists would rather say, *actants*) (Latour, 2005).

In principle, ANT avoids the recourse to heavy theoretical equipment and prefers to focus on the actors' own accounts, explanations and meta-languages. Its vocabulary strives for simplicity: it is supposed to convey as little meaning as possible so as to let the cases it describes deploy fully. As Latour explained, ANT theorists have attempted to constitute an "infra-language" that can account for the actors' movements without interfering with them (Latour, 2005, p. 30). This vocabulary has however diversified, refined and sophisticated over the years. Since ANT is supposed to be at the service of description (and not the other way round), it is natural that it should have evolved and sharpened with each new description.

Though its vocabulary remains both general and flexible, it is set to stay in line with a few basic principles – and to this extent ANT can indeed be considered as a theory. Terms such as actants, actors, mediation, translation, composition, assemblage, arrangements, attachments, or even thing, are easily reinterpretable and adaptable to specific situations, and, at the same time, the ideas and methods they convey are quite precise. Somewhat like "boundary objects" (Star & Griesemer, 1989), ANT vocabulary is flexible, but it is nonetheless sufficiently precise and calibrated to ensure that those using it stick to the same methodological ground. This ambivalence of ANT – its being a theory founded on theoretical agnosticism, the fact that it relies on imprecise terms to achieve details and precision – is a crucial part of its strength and originality, but it is also what makes it so delicate to handle.

Here, I would like to stress three points to which ANT is particularly attentive and that it has to a large extent reformulated and re-problematised: ***relationality***, ***agency***, and ***multiplicity***. Once these notions are clarified, I will attempt to put them at work to propose a refined problematisation of the modularity of photovoltaics.

2.1.1. Entities configured in relations

The commitment of actor-network theorists to describe constitutive moments by following actors and things as they are made and make their worlds is paired with an attention to the association, composition, assemblage and holding together of groups, objects and agencies.

As transpires from the notions of hybrid forums or matter of concerns, and from the oxymoronic character of the expression "actor-network" (Law, 1999), ANT conceives of **entities as defined through relations**, and even as "performed in, by and through the relations in which they are located" (Law, 1999).

Highlighting the importance of ***relationality*** (or, as he called it earlier on, "relational materiality" (Law, 1999)), John Law defines ANT as

> "an approach to sociotechnical analysis that treats entities and materialities as *enacted and relational effects,* and explores the *configuration and reconfiguration of their relations*. Its relationality means that major ontological categories (for instance 'technology' and 'society', or 'human' and 'non-human') are *treated as effects or outcomes*, rather than as explanatory resources. Actor-network theory is widely used as a toolkit in sociotechnical analysis, though it might be better considered as a sensibility to *materiality, relationality, and process*" (Law, 2004, p. 157, emphasis added).

The range of relational entities is thus to be understood widely: objects, actors and interests, but also categories, hierarchies and "contexts"[14] are considered as **relational outcomes**, and as such they cannot be used as explanations. Either they take part in the process described, and their (re)configuration as well as the way they (re)configure other entities should be described and accounted for, or they do not leave traces of intervention and therefore need not be considered (Latour, 2005). For instance, when Akrich describes the co-constitution of a technological object and of its environment, she points out that in the end, "there should not remain in the description any element that could be related to the category of 'context', i.e. that would not be in some way translated by the object itself" (Akrich, 1989, p. 33, author's translation).[15]

[14] I put "context" between inverted commas because this notion is rather problematic in ANT: since it is considered to hold no analytical value, its use is usually avoided; the best way to define it in actor-network terms might be as all that does not intervene in the process under consideration, but then there is little need to refer to it. However, what is part of the "context"; i.e., out of the perimeter of analysis, is not fixed: in instances of overflows, things that were externalised claim attention and thereby move out of the context.

[15] "Plus que de suivre strictement l'élaboration d'un système technique, il s'agira de montrer la genèse simultanée de l'objet et de son environnement: en découvrant les différentes machines et leurs composants, nous verrons apparaître des pans de société ou de géographie nicaraguayenne, de sorte qu'il ne devrait plus rester, dans cette description, aucun élément que l'on puisse

This attention to the **making of associations** stems for the methodological choice to follow things in-the-making and from a thorough interpretation of the symmetry principle. As Callon explained it in his seminal article on the scallops of the Saint-Brieuc Bay, categories, identities and positions are precisely what is at stake in the type of situations ANT has been interested in (Callon, 1986).

> "The observer must abandon all a priori distinctions between natural and social events. He must reject the hypothesis of a definite boundary which separates the two. These divisions are considered to be conflictual, for they are the result of analysis rather than its point of departure. Further, the observer must consider that the repertoire of categories which he uses, the entities which are mobilized, and the relationships between these are all topics for actors discussions. Instead of imposing a pre-established grid of analysis upon these, the observer follows the actors in order to identify the manner in which they define and associate the different elements by which they build and explain their world, whether it be social or natural." (Callon, 1986)

2.1.2. A relational definition of agency

The focus of actor-network theorists on the configuration and reconfiguration of heterogeneous (and "uncertain and reversible, at least in principle" (Law, 1999)) associations in which non-human plays as much of a part as humans entails a specific reading of actors, action and agency. ANT breaks with traditional theories of agency in that it is based on no stable theory of action but instead presumes the "radical indeterminacy of the actor" (Callon, 1999). The **identity of "actants", as much as their capacity to act and their interests, are never considered as fixed**: they are **configured in relations**. But it also followas that not only humans act: actants can take many shapes, and they cannot be listed a priori. Or, as Law sums up Callon's 1986 propositions:

> "What there is and how it is divided up should not be assumed beforehand. Instead it arises in the course of interaction between different actors. But note also that *for Callon what counts as an actor can only be determined in the course of interaction. Actors are entities, human or otherwise, that happen to act. They are not given, but emerge in relations.*" (Law, 2004, p. 102, emphasis added)

Thus, for ANT**, agency is relational**. This has three major implications for how action is accounted for: agency is **distributed among hetereogeneous entities**, making the source of action difficult to identify; **"actants", then, do not have fixed contours** and their capacity to act depends on their capacity to interest and enrol others; and **action is never fully predictable** since it involves series of displacements, translations and mediations.

(1) First, **agency is conceived as distributed among heterogeneous entities**, meaning that it is spread among several human and non-human actants, that it consists of sequences which order can vary depending on the events, and that none of the participants in the action can be considered independently from the others (Callon, 2008).

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rapporter à la catégorie du 'contexte', c'est-à-dire qui ne soit pas en quelque sorte traduit par l'objet lui-même." (Akrich, 1989, p. 33)

For ANT, **identifying the source and the effects of action is never straightforward**: action, understood as the transformation of a situation by the production of differences (Callon, 2008, p. 38), stems from heterogeneous assemblages and is very diverse in its content, nature and effects (Callon, 2008). In concrete terms, it implies for ANT,

> "agency as a capacity to act and to give meaning to action can neither be contained in a human being nor localised in the institutions, norms, values, and discursive or symbolic systems assumed to produce effects on individual. Action, including its reflexive dimension that produces meaning, takes place in hybrid collectives comprising human beings as well as material and technical devices, texts, etc." (Callon, 2005, p. 4).

Thus, agencies are "made up off human bodies but also of prostheses, tools, equipment, technical devices, algorithms, etc." 'and, since they "are made they can be (re)made, at least to some extent" (Callon, 2005, p. 4).

Once again, heterogeneity is crucial, as Latour pointed out:

> "Any course of action will thread a trajectory through completely foreign modes of existence that have been brought together by such heterogeneity." (Latour, 2005, p. 75).

The vocabulary used by ANT to capture this distributed, heterogeneous character of action has oscillated between several terms, among which associations (Latour, 2005), assemblages (DeLanda, 2008), socio-technical arrangements (Barry, 2001) and socio-technical *agencements* (Callon, 2005, 2008; Caliskan & Callon, 2010).[16] The variations in meaning between those terms do not mask what they have in common, which is to stress that **action depends on the successful articulation of heterogeneous components**.

Thus, action and its origin(s) are always uncertain and problematic, and ANT is precisely interested in this uncertain and problematic dimension of action: as Latour notes, "If an actor is said to be an *actor*-network, it is first of all to underline that it represents the major source of uncertainty about the origin of action" (Latour, 2005, p. 46).

(2) Indeed, a second implication of this relational perspective is that **actants are not fixed, unified entities with determined interests and objectives**. They not only emerge in relations, but can vary in shape, size and influence over the course of the process. Their **capacity to act depends on their capacity to enrol and interest others**, or in other words, to create and maintain relations (Callon, 1986; Barry & Slater, 2002). The global, macro or dominant character of an entity thus derives from the scope and durability of the network of connections it has weaved, and it is never irreversible, at least in principle (though objects and techniques may durably solidify certain connections, Latour, 1994, 2005, 2012) (Callon & Latour, 1981). It follows that

> "the ANT actor may, alternately and indiscriminately, be a power which enrols and dominates or, by contrast, an agent with no initiative which allows itself to be enrolled" (Callon, 1999, p. 182).

This conception enables actor-network theorists to move beyond the classical dichotomy between individualism and holism or between agent and structure (Latour, 1994; Callon & Law, 1997; Callon, 1998). The term "actor-network", after all, incorporates the tension

[16] These terms, and especially that of "*agencements",* will receive more attention in Chapter 2.

between structure and agency by combining them (Law, 1999). Callon (1998) has drawn on Granovetter (1973) to specify how a relational conception of action can lead to the reconfiguration of the notions of "agent" and "network" and to an understanding of "structure" not as a framework, but as an outcome of fluctuating relations.

According to Granovetter, he writes, network "configure ontologies. The agents, their dimensions and what they are and do, all depend on the morphology of the relations in which they are involved" (Callon, 1998, p. 8). It follows that

> "the network, in this sense, does not link agents with an established identity (that is to say, endowed with a set of fixed interests and stable preferences) to form what would be a rigid social structure constituting the framework in which individual actions are situated. […] In the social network as defined by Granovetter, the agents' identities, interests and objectives, in short, everything which might stabilize their description and their being, are variable outcomes which fluctuate with the forms and dynamics of relations between these agents" (Callon, 1998, p. 8). Then, "the agent is neither immersed in the network nor framed by it; in other words, the network does not serve as a context. Both agent and network are, in a sense, two sides of the same coin" (Callon, 1998, p. 8).

(3) Yet, and this is the third implication of relational agency, an actor-network *cannot* be reduced to a sum of relations. Because it is diverse and heterogeneous, **action is always potentially overflowing and to an extent unpredictable**. Since action is distributed, no single entity is entirely in control: every one of the relations through which an actant emerges implies a transformation.

The two key notions of ***translation*** (Callon, 1986) and ***mediation*** (Hennion, 1993, 2013) were coined precisely to convey the **series of alterations** that constitute action. Both imply a displacement, the passing of something from one entity to another that allows action to be pursued and actants to be unified, but also – and crucially – a transformation: that which passes changes as it is being passed.

Michel Callon proposed the vocabulary of ***translation*** (which also included the notions of *intéressement*, enrolment and spokesperson) to describe the "series of unpredictable displacements" that lead "all the actors concerned to pass, through various metamorphoses and transformations, by [the spokespersons constituted as obligatory passage points]" (Callon, 1986). It offers a strategic perspective on the displacements, transformations, negotiations and adjustments that are necessary to bring separate universes and entities together, thereby providing a manner to account for the emergence of power relationships.[17] But it also stresses the contestable nature of these power relationships, which can always be overturned: translations, indeed, are never perfect, "from translation to treason there is only one short step" (Callon, 1986).

Because of this imperfection, of the displacements and transformations (often material) that they imply, "translations" have been instrumental in underlining what distinguishes an "actor-network" from an "actor with a network". For ANT, an actor

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[17] "To translate is to displace: the three untiring researchers attempt to displace their allies to make them pass by Brest and their laboratories. But to translate is also to express is one's own language what others say and want, why they act in the way they do and how they associate with each other: it is to establish oneself as a spokesman. At the end of the process, if it is successful, only voices speaking in unison will be heard." (Callon, 1986, p. --).

> "is the list of its relations *plus* the transformation that each of the items in the list has undergone *in the neighbourhood* or *on the occasion* of this relation. This little something that we add on the sly has received a canonical name: that of *translation*" (Latour, 2010, p. 258, author's translation).[18]

The point of the concept of "***mediation***", originally proposed by Hennion (Hennion, 1993) and then developed by Latour (Latour, 1991,1994a, 2005), is to focus attention upon these successive and unpredictable transformations and displacements that make up action. From an ANT standpoint, saying that action is mediated means insisting on the inevitable overflows of action: as opposed to an "***intermediary***", a "***mediator***" always **does more than just carry a cause to its effect**; it always displaces, sparks, transforms, sets in motion other entities, thereby producing novel, unpredictable situations. "Faire, c'est faire faire", to take up Latour's remarkably untranslatable formulation (Latour, 1994, p. 51).[19] Therefore, action is not distributed among passive intermediaries, but passes through "concatenations of mediators where each point can be said to fully act" (Latour, 2005, p. 59).

2.1.3. Multiple realities enacted by a variety of practices and material settings

The notion of "mediation" is useful to embrace the indeterminacy or under-determinacy of action, since it leads to considering "each point as a mediation, that is to say as an event that could not be defined by its inputs, by its outputs, by its causes or by its consequences" (Latour, 1994b, p. 50, author's translation).[20] But it takes us further than this in our redefinition of entities as relational.

Indeed, insofar as actors and objects emerge through relations negotiated via series of translations and mediations, **any attempt to define essences is vain**. Entities do not pre-exist with a list a stable defining qualities; their contours are not fixed but "fluctuate with the extension and transformations of the network" (Gomart, 2002, p. 98). With ANT, any attempt to define an actor or an object inevitably leads to the deployment of the relations and attributes that it is made of, granted that if you "change any of the relations, you necessarily change the definition of what is acting, since the actor is never anything else than the support brought by the multitude of the associates" (Latour, 2010, p. 262, author's translation).

As mentioned above, STS are interested in the constitution of entities: it follows that constituted entities are not what one starts with but rather what one seeks to account for. Entities are conceived as " 'performed by' specific trials and associations", as "achievements shaped in and through practices" (Gomart, 2002, p. 98). The focus is not only directed on relations but on practices as well.

[18] "Ou plus exactement (mais s'agit-il simplement d'une habilité de langage?), un acteur c'est la liste de ses relations *plus* la transformation que chacun des items de la liste a subi *au voisinage* ou *à l'occasion* de cette relation. Ce petit plus que nous ajoutons en douce a reçu un nom canonique: celui de *traduction*." (Latour, 2010, p. 258)

[19] This would approximately translate as "to do is to make do" or "let do".

[20] "Il faut considérer tout point comme une médiation, c'est-à-dire comme un événement qui ne saurait se définir ni par ses entrées, ni par ses sorties, ni par ses causes, ni par ses conséquences."

In her studies of medical practices and diagnoses, Annemarie Mol (1999; Law, 2004) has described how various practices shape realities by enacting single entities in multiple ways. One of her example is that of anaemia (Mol, 1999). She shows that anaemia can be diagnosed in several ways, each one involving a distinct set of practices: clinical, statistical and pathophysiological. None of these anaemia is more "real" than the others; though they enact it differently, the three practices point to the same anaemia, that is to a single object. Even a unified entity such as anaemia can retain a form of ***multiplicity*** insofar as it can be enacted through a diversity of practices.

Mol uses the term "multiplicity" to denote the particular approach to ontology that she crafts through her case studies. As opposed to "pluralism", in her notion of "reality as multiple", alternatives are not mutually exclusive: **different versions of an object can coexist** (Mol, 1999). There is not one reality "out-there" to which we would only have partial access through different perspectives and observations; rather, there are **objects that are enacted, performed and manipulated using various tools in the course of diverse practices** (Mol, 1999).

Hence the definition that Law gives of multiplicity as

> "the simultaneous enactment of objects in different practices, when these objects are said to be the same. Hence the claim that there are many realities rather than one. This arises because practices are endlessly variable and differ from one another" (Law, 2004, p. 162).

Emilie Gomart makes a similar argument in her study of methadone (Gomart, 2002). In analysing two distinct experiments with methadone, she seeks to apprehend the elusive character of a "substance" that has very different effects and characteristics in different instances. To do so, she breaks away from a conception of drugs as constituted substances that can manifest themselves or be interpreted in different ways but never have "new properties", only "newly-*discovered* properties" (Gomart, 2002, p. 95). Instead of relying on a substantial definition of methadone, she approaches it as a relational entity. The substance is not here from the start; it is an **achievement that can only be reached at the end of the trials set up by experimenters**. Her approach to methadone directly draws on the indeterminacy of action postulated by actor-network theory, of which she makes a radical interpretation:

> "There is a moment in the course of action when the question of the identity of actors (who they are, what they are capable of) has *not yet* been posed. Only later will there be a time when it finally becomes possible to say that it was methadone that acted and that it has inherent properties. An action cannot be explained by the nature of its source; rather, the source is a *post hoc* achievement." (Gomart, 2002, p. 99)

Since action and most crucially its sources are undetermined, Gomart directs her attention not towards "who acts" but "what occurs", that is to say **towards effects and how they are performed**. Her focus is on "these actions that localize, temporize, embody, subject, 'frame'" entities (Gomart, 2002, p. 98), and most specifically on the set-ups or *dispositifs* understood as "what allows [entities] to achieve an autonomous status" (Gomart, 2002, p. 98). "The shift to the 'performance' of entities, she pursues, has meant a focus on the exact meaning of the 'construction' of entities in a *dispositif*" (Gomart, 2002, p. 98).

The "*dispositif"* is not to be understood in a deterministic way as something that reveals or provides access to an entity (in the case of methadone, a substance). Much to the contrary, the notion is close in meanings to the terms "mediation", "events", "emergence" or "attachment" that actor network theorists use to render their interpretation of action as excessive, undetermined, overflowing and delegated by shifting the focus from "the interior of objects (which are discovered as they always already were) to what 'emerges'" (Gomart, 2002, p. 99). The *dispositif* is "that which lets/makes happen" (Gomart, 2002, p. 99).

2.2. Approaching photovoltaics as modular technologies

Mol's and Gomart's studies are helpful to approach multiplicity and tackle ill-determined objects. Mol and Gomart have both focused on elusive entities that cannot be reached without being mediated through practices, and their approach indeed seems more directly applicable to this type of objects. However, their theoretical project is more general in scope. Their aim is to contribute to the development and refinement of the ANT theorisation of agency and actors; in principle, any actant may be approached as multiple, emergent or performed through relations, mediations, translations and *dispositifs*.

To what extent can the approach in terms of multiplicity be applied to photovoltaics? Can they help grasp the modularity of photovoltaic technologies? More generally, how instrumental can they be to delineate photovoltaics as an object of study without overlooking their fluidity, their modularity and their emergent character?

It would seem at first that, contrary to anaemia or methadone, photovoltaics are "hard" technical objects with palpable and material contours. As opposed to methadone, it seems that photovoltaics *can* be observed independently from their effects, or at least that photovoltaic technologies can: an unplugged solar panel is still a solar panel, even though it is very different from a plugged one. However, the difference is not as important as it would first appear to be.

Originally, "photovoltaic" is an adjective that refers to a specific effect, and is used to describe technologies that perform this particular effect (i.e. the production of electricity using the energy of photons) or the electricity they generate. In other words, what characterises a technology as "photovoltaic" is not its design or its material, technical form, but the fact that it performs the photovoltaic effect to generate electricity from light. From this standpoint, it makes sense to approach photovoltaics as a diverse and multiple entities with fluctuating contours, that can be assembled in various way and that are defined by the function they perform and the effects they produce.

ANT has been particularly interested in the "detours" of techniques (Latour, 1994b, 2010; Akrich, 1989) and in accounting for the peculiar courses of action involving technological objects. How do these objects emerge and how are they displaced, adapted, sometimes hijacked? What kinds of relations/translations are formed between designer, object, user and effects? How is action delegated to objects, and to what extent do objects deviate from it and produce unexpected effects? What are objects made to do, and what do they make happen?

Gomart sums up these interrogations in a footnote of her article on methadone, retracing the move from facts to things in STS:

> "Just as the autonomy of facts is constructed through experimental techniques so the specificity (what makes them unique) of objects is obtained in relation to other actants. In other words, specificities of the object emerge as relevant in the course of action, and only in relation to other pertinent elements of the setting. [...] The very capacity of certain entities to act in unexpected ways – transforming, for instance, the project of the designer – is emergent in the setting. 'Resistance' describes these entities as both (1) emergent in relation to, in reaction to the *dispositif*, and (2) as never reducible to the sum of the forces which went into their production. To use a well-known example, things do not simply implement the designer's plans but prolong and *deviate from*, in unexpected ways, the action which was delegated to them" (Gomart, 2002, p. 129).

2.2.1. "Fluid" technologies

Among the many proposals by actor-network theorists to seize the specificities of technologically-mediated action, de Laet and Mol's notion of "***fluid technologies***" is particularly relevant to photovoltaics (de Laet & Mol, 2000). It finds its origin in the study of a water pump developed in Zimbabwe, the "Zimbabwe Bush Pump", which is "solid and mechanical and yet, or so [they] argue, its boundaries are vague and moving, rather than being clear or fixed" (de Laet & Mol, 2000, p. 225).[21] As they show in their review of the characteristics of the Bush Pump, one knows a Bush Pump when one sees it, yet, defining what it is and what it means for it to be working or not working can be tricky. The Bush Pump, they write,

> "is not well-bounded but entangled, in terms of both its performance and its nature, in a variety of worlds. Those begin to change more or less dramatically as soon as the Bush Pump stops acting. Yet it is not clear *when* exactly the Pump stops acting, when it achieves its aims, and at which point it fails and falters. That is what we also mean to capture when we use the term *fluid*. If the Bush Pump may be called an 'actor' despite its fluidity, then 'actors' no longer (or not always) *need* the clear-cut boundaries that come with a stable identity. Not only can actors be non-rational and non-humans; they can also – or so we hope to demonstrate – be fluid without losing their agency" (de Laet & Mol, 2000, p. 227).

In de Laet & Mol's description, a **fluid technology** is characterised by its having "a number of possible boundaries" and being "– descriptively and practically – framed in a range of different ways" (de Laet & Mol, 2000, p. 237). The variety or fluidity of the object boundaries should not be understood to imply that it is "vague or random, that it is *every*where or *any*thing"; rather, they "define a limited set of configurations. They each, one might say, *enact* a different Bush Pump" (de Laet & Mol, 2000, p. 237).

In their analysis, de Laet and Mol list five configurations that enact different Bush Pumps:

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[21] De Laet and Mol give the following description of the pump: "The Zimbabwe Bush Pump 'B' type consists of a pump head or water discharge unit, a base or pump stand, and a lever. The steel pump stand is bolted to the bore hole casing at one end and to the water discharge unit at the other. The lever is a flexibly fixed wooden block, joined with bolts to the upper part of the water discharge unit." (de Laet & Mol, 2002, pp. 228-9)

> "The Pump is a mechanical object, it is a hydraulic system, but it is also a device installed by the community, a health promoter and a nation-building apparatus. It has each of these identities – and each comes with its own different boundaries" (de Laet & Mol, 2000, p. 252).

The boundaries of the pump are thus constituted by the different objects, actors and issues that can be associated with it: its material components, the water it gives access to, the village community that installs it, etc…

Like the Bush Pump, photovoltaics can be enacted in different configurations and adapted, re-interpreted by those implied in some of these configurations. However, they are even more diverse and surprising technologies than the Bush Pump is, and listing these configurations exhaustively is beyond the scope of this dissertation.[22] The fluidity of photovoltaics, I would like to argue here, shares similarities with that of the Bush Pump but stems from different characteristics of the technology – its modularity being a crucial one. Photovoltaic technologies can be described as fluid insofar as they exist in different versions according to their configuration, which enables them to be easily re-appropriated and customised. The basic units of photovoltaic system are photovoltaic *modules,* which are stabilised sets of photovoltaic cells that can be connected to virtually any number of other modules and plugged into an electric installation. The ***modularity*** of photovoltaic technologies thus adds something to their fluidity.

2.2.2. Beyond fluidity: the modularity of photovoltaics

If photovoltaics are so difficult to define with precision, it is in large part because the term "photovoltaics" does not designate *one* technology, but refers to an effect which can be performed by a diverse set of technologies. The Bush Pump is a diverse technology to an extent, since there exists several versions of it, all of which can be adapted and modified in sometimes unintended ways, but this is nothing compared to the diversity of photovoltaic systems. Indeed, with photovoltaics it is not simply a matter of different versions and adaptations of a single technology, but of broadly different technological configurations of extremely diverse scales.

These assemblages share two core characteristics: the first one, to which they owe their generic name, is that they are based upon photovoltaic cells and modules that all work according to the same principle; the second one is their modularity.

2.2.2.1. Photovoltaic cells

The basic component of photovoltaic technologies is the photovoltaic cell. A photovoltaic cell is a device that generates electricity from light by exploiting the photovoltaic principle. The IPCC SRREN describes their functioning as such:

> "Light shining on a semiconductor such as silicon (Si), gallium arsenide (GaAs), copper indium disilenide ($CuInSe_2$), or cadmium telluride (CdTe) generates electron-hole pairs that are separated spatially by an internal electric field. Negative charges are on one side

[22] For instance, photovoltaic is the module unit produced by a Chinese firm, the system installed on an individual's roof, as well as a renewable energy technology that can contribute to the achievement of environmental objectives (cf. Chapter 3), or what gathers the group of farmers that carried out a mutualised photovoltaic project near Figeac (cf. Chapter 5).

> of the cell and positive charges are on the other side. This resulting charge separation creates a voltage. When the two sides of the illuminated cell are connected to a load, current flows from one side of the device via the load to the other side of the cell." (Arvizu et al., 2011, p. 23)

Photovoltaics are thus primarily defined by the principle at play within photovoltaic cells. Since several semi-conductors are suitable material for making photovoltaic cells, there exists a range of technologies able to perform the photovoltaic effect. The oldest[23] and dominant one is wafer-based silicon technology, which itself can take several forms (mono- and multicrystalline) (Arvizu et al., 2011, p. 24). An alternative set of photovoltaic technologies is that of thin-film solar cells, which consist of photosensitive semiconductors films spread on a glass, plastic or steel frame. Here again, thin-film photovoltaic cells can be made using diverse material systems: amorphous silicon, amorphous silicon-germanium, microcrystalline silicon, cadmium telluride, copper indium gallium diselenide or disulfide (CIGS) (Arvizu et al., 2011, p. 25)… Other, less developed or stabilised types of photovoltaic cells include multijunction and heterojunction cells (more expensive but more efficient, these can be used in concentrating photovoltaic systems), dye-sensitized solar cells and organic photovoltaic cells (Arvizu et al., 2011, p. 26).

Once a solar cell has been assembled, it makes no fundamental difference which technology and materials were used to make it, at least as far as its function is concerned: different photovoltaic cells technologies will have different characteristics, but their range of applications is roughly the same.[24] One could say that the "active principle" of photovoltaics is encapsulated within cells that then become black boxes (literally as well figuratively, since most solar cells are dark). Photovoltaic cells, whatever their type, can be characterised by a set of parameters that make them comparable and displaceable: efficiency, costs, durability, availability of raw materials, etc… Once these characteristics have been determined, a specific photovoltaic cell can be defined without need to re-open the black box and considering the details of the reactions at play.[25]

Photovoltaic cells can thus be considered as modular by design: a photovoltaic cell is an independent unit that is characterised by a set of (more or less) standardised

[23] The first Silicon solar cell was developed by the Bell Laboratory in 1954 for powering satellite application (International Energy Agency, 2011).

[24] This may not hold as much when emerging photovoltaic technologies, i.e. multijunction and organic cells, are concerned; indeed, the characteristics of these two technologies make them more suited to specific uses (concentrated photovoltaic for multi-junction, small-scale, nomad applications for organic films). However, in theory at least, they remain substitutable with other types of photovoltaic cells.

[25] As with any technology, the black box can be re-opened when problems or unforeseen demands or constraints arise. For instance, concerns regarding the toxicity of cadmium have drawn attention to the actual composition of CdTe cells; the potential scarcity of specific materials such as Indium have led researchers to 're-open' CIGS cells to try to reduce the quantity of Indium needed; specific industrial demands, or the need to drastically increase efficiency, are other examples of situations that can make processes matter again (Interview 7). However, for the purpose of this dissertation, I will consider photovoltaic cells as stable enough to be viewed as black boxes: those which commercial use is widely spread are stabilised entities.

parameters which make it comparable to other photovoltaic cells, and that can then be assembled in a variety of ways.

Table 2 Existing photovoltaic technologies and their best efficiency as of 2011 (Arvizu et al., 2011, pp. 23-26).

Type of photovoltaic cells		**Best efficiency**		**Market share**
		Laboratory	**Commercial**	
Existing technologies				
Wafer-based crystalline silicon	Multicrystalline	20.3%	12-14%	About 80%
	Monocrystalline	25.0%	14-20%	
Thin-film	Amorphous silicon	10.1%		20% in 2009, 13% in 2010, 11% in 2011 (Bazilian et al., 2013)
	Microcrystalline silicon			
	CIGS CIS	20.1%	13.1% 8.6%	
	CdTe	16.7%	10-11%	
Emerging technologies				
Organic photovoltaic	Single junction	~ 5%		
	Bulk-heterojunction	7.9%		
Dye-sensitized solar cells		10.4%		

2.2.2.2. Modulations

On its own, a photovoltaic cell is of little use; to be turned into an electricity-generating device, it needs to be assembled to others and encapsulated within a photovoltaic module, which will then be assembled to other modules to constitute a photovoltaic panel. Both module and panel can be considered as black boxes and are as modular as the photovoltaic cells they comprise of. However complex the processes at play in its functioning, a photovoltaic panel is a closed-up, independent, standardised, and easily displaceable object.

Modularity is not an inherent property of photovoltaic technologies: there existed applications for photovoltaic cells before the stabilisation and commercialisation of photovoltaic modules. As Green (2005) relates, the first silicon module for outdoor use was developed in 1955 by the Bell Laboratories, only one year after they produced the first “reasonably efficient silicon cell” (Green, 2005, p. 447). It was “an assemblage of 48 M2028 sub-modules each approximately 10 cm square, each sub-modulee consisting of 9 rear-contacted cells of approximately 3 cm diameter encapsulated in silicon oil in a plastic case” (Green, 2005, pp. 447-8). However, photovoltaic modules did not attract significant industrial or commercial interest until the mid-1970s. At the time, spacecraft was the main application for photovoltaics and virtually no market existed for terrestrial applications.

Driven by a re-evaluation of the interest of the terrestrial applications of photovoltaics, companies such as Sharp, Philips and Solar Power developed small commercial modules in the mid-1970s (Green, 2005).[26] Government-sponsored procurement programmes in the US and the development of the use of photovoltaics in telecommunication systems provided an outlet for photovoltaic modules, leading to significant progress in module design, robustness and reliability. Focus was on the elaboration of encapsulation materials techniques to best protect photovoltaic cells for outdoor applications, increase the durability of modules and take advantage of the reliability of photovoltaics. By the mid-1980s, module design had stabilised and "almost all manufacturers had converged towards a common module design which has since proved itself extremely rugged and reliable in the field" (Green, 2005, p. 447). Attention turned towards increasing the efficiency of solar cells (Green, 2005, p. 450).

As much as the development of photovoltaic modules making outdoor terrestrial applications resulted from the emergence of markets for such application, the increased attention for grid-connected photovoltaics has led to evolution in the assemblage of photovoltaic technologies. In the perspective of large-scale, grid-connected electricity generation, photovoltaic panels have to be further assembled to a set of elements that will ensure their connectivity and reliability, among other things. These are commonly referred to as the "Balance of Sytem" (BOS). Together, the photovoltaic panel(s) and the BOS constitute a photovoltaic system. The BOS is an assemblage of heterogeneous elements which composition can vary according to the size and function of the photovoltaic system and depending on whether it is connected to the electric grid or not. A brochure by the Gimélec [Groupement des industries de l'équipement électrique, du contrôle-commande et des services associés] illustrates the diversity and heterogeneity of the components and actions that are necessary to make a grid-connected photovoltaic system work: panels to produce photovoltaic electricity, switches, lightening arresters, junction boxes, electric connectors, inverters to convert direct current into alternative current, monitoring devices, meters, etc… (Gimélec, 2009, p. 6-7).

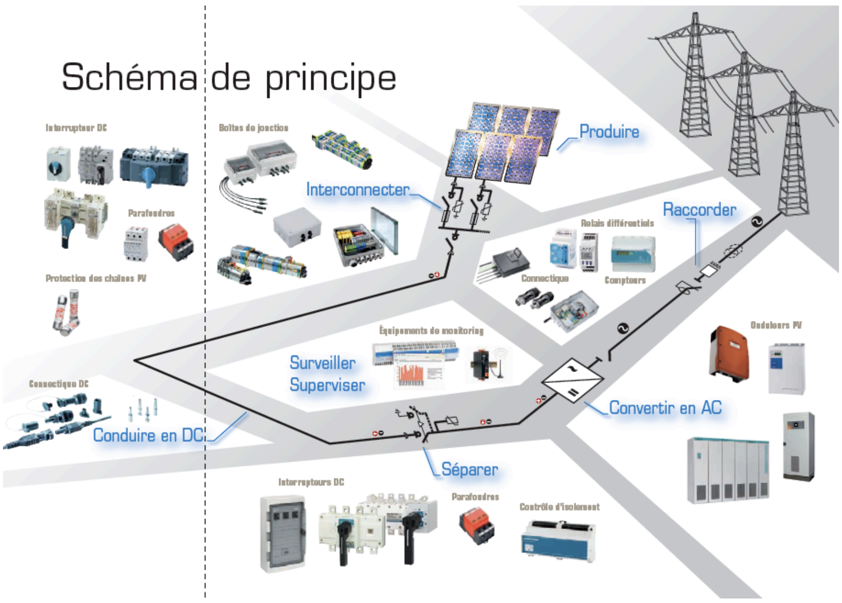

Figure 6 Assembling grid-connected photovoltaics (Gimélec, 2009, pp. 6-7)

[26] The bibliography of Green's paper on the history of photovoltaic modules indeed suggests that the term "solar cell module" appears in the late 1970s in scientific communications, and "photovoltaic modules" in the 2000s.

Photovoltaic systems, on top of being variable and heterogeneous assemblages, can take extremely different forms: the size and number of photovoltaic panels can vary from one to several hundreds, they can be mounted on the ground, on a small or a large roof, on a "maison à énergie positive", on a device that will follow the daily movement of the sun (photovoltaic trackers), on small appliances…[27] The manner of using and dispatching the electricity generated can also vary widely, since the system can be isolated and include devices for stocking electricity or connected to the electric grid. The electricity produced can thus be used exclusively onsite, used partly onsite and partly dispatched onto the grid, fed into a local (smart) grid, entirely fed into either the low- or high-voltage grid… Tables 3 and 4 sum up key characteristics of the currently most common types of photovoltaic systems, highlighting the diversity of forms that photovoltaic system can take.

Once a photovoltaic system is installed, it can be considered as stabilised in its form. Yet, what is fascinating is that the photovoltaic panel that fuels an energy-intelligent house, the solar-powered calculator, and the huge photovoltaic plant in the Mojave Desert all started from a similar photovoltaic cell. The fate of solar cells is not inscribed from the start: they are initially undetermined, and gain specificity as they are progressively assembled with other elements. To use a – perhaps audacious – biological analogy, one could talk of "stem photovoltaic cells": initially, they are all similar, and they potentially can serve as building blocks for an incredible variety of systems; the final form of the assemblages they will take part in is determined by the series of gradual encapsulations, transformations and connections they undergo. And, in principle, any photovoltaic module that is still functioning could be taken from an installation and plugged into completely different one.

Then, defining photovoltaics is not so much a matter of delineating boundaries, even if they are multiple and variable, but of retracing configurations of photovoltaics that can vary in scale and scope, in terms of the number of entities they assemble and actions they put into play and depend on, and of the number of entities they connect and reach. The difference between modularity and fluidity is that modularity does not only enables photovoltaic technologies to be arranged in various ways while retaining their function; it also allows for the aggregation of a large number of similar modules into large-scale photovoltaic systems. Combining several Bush pumps together would be of little use: it would not enhance the capacity of the first pump. On the contrary, adding a photovoltaic module does not make a big difference in terms of work involved or final function, but it increases the amount of electricity generated, thus enhancing the overall performance of the installation. The modularity of photovoltaic technologies is then a source of proliferation: it means that photovoltaic installations can multiply in size as much as in numbers or forms. This is indeed what happened in Spain, where feed-in tariffs led to the installation of huge ground-mounted photovoltaic plants that generated large quantities of electricity.

[27] And this list does not include photovoltaic "systems" that comprise of only a few cells incorporated into a small device, such as those that fuel electronic calculators.

Table 3 The three main types of grid-connected photovoltaic installations (translated from Gimélec, 2010, p. 6)

	A residential installation	**An installation on a commercial building**	**A generation plant**
… of an average power of:	3 kWC	250 kWC	4 MWc
… represents:	25 m^2 of crystalline silicon modules integrated to a rooftop	6000 m^2 of thin-film modules on impermeability cover	80 000 m^2 ground coverage
… costs (materials, installation and connection):	7 to 8 k€ / kWc	5.5 to 6 k€ / kWc	4.5 to 5 k€ / kWc
… and produces annually:	3,000 to 3,500 kWh	250 to 300 MWh	4,000 to 5,000 MWh

Table 4 Photovoltaic applications as classified in Arvizu et al., 2011, pp. 27-29.

<table>
<tr><td rowspan="2">Off-grid photovoltaic</td><td colspan="2">Isolated sites</td></tr>
<tr><td colspan="2">Centralized photovoltaic mini-grid for village electrification</td></tr>
<tr><td rowspan="4">Grid-connected photovoltaic</td><td rowspan="3">Distributed
(Building integrated or not)</td><td>Residential
1-4 kWc</td></tr>
<tr><td>On public, commercial or industrial buildings
10 kWc to several MWc</td></tr>
<tr><td>In the built environment (e.g. motorway sound barriers, parking lots...)</td></tr>
<tr><td colspan="2">Centralized (ground-mounted solar plants)
Over 1 MWc</td></tr>
<tr><td>Consumer applications</td><td colspan="2">e.g. calculators, portable charging devices…</td></tr>
</table>

2.2.3. Grid connection and the massification of photovoltaic electricity generation

Defining photovoltaics as an object of study is challenging not only because photovoltaic technologies are modular, but also because photovoltaics as contributors to mass electricity generation is emergent, that is to say in the process of developing and taking shape. Increased interest for grid-connected photovoltaics as an alternative for electricity generation has indeed triggered dramatic evolutions in the sector, particularly over the last ten years.

These recent evolutions have led to the appearance of novel kinds of photovoltaic systems, as well as to the massification of photovoltaic markets. Grid connection has pulled photovoltaic electricity out of the niches in which it had been confined, turning it into a contender on large-scale electricity markets. Most of these changes are recent, especially when considering the inertia of such large-scale systems as electricity markets. Grid-connected photovoltaics are not yet fully stabilised and still give way to experimentation with various types of photovoltaic assemblages, leading to a proliferation of the forms of photovoltaic installations on top of their proliferation in numbers. The development of grid-connected photovoltaics remains hardly predictable, and the prospect for this new source of electricity cannot be extrapolated from the evolution and characteristics of other, more stable objects (Interview 17).[28]

This proliferating emergence is a relatively recent phenomenon, and as such it is part of what makes photovoltaics puzzling. For several decades, photovoltaics were confined to stable niche markets, such as autonomous electricity generation systems in remote locations or spatial applications, and advocates of solar power were barely heeded. Laboratory research contributed to increasing cells efficiency, developing new processes and driving costs down, but the evolution of photovoltaics was overall predictable; at least, it was not as surprising as it has been for the last ten years.[29] For sure, photovoltaic cells are now much less expensive than they used to be fifteen to twenty years ago, but that does not nearly explain how a somewhat dormant technology was suddenly sparked into emerging and proliferating on a much larger scale and in very diverse forms. How did photovoltaics end up emerging as a serious option for large-scale electricity generation? How did grid-connected turn photovoltaics into the dominant application for photovoltaics? What can account for the massification and commodification of photovoltaic technologies and electricity?

I suggest that this has to do, in part, with the modularity of current photovoltaic technologies and of the "black-boxing" that it entails. Photovoltaic modules were originally designed to protect photovoltaic cells and ensure the robustness and reliability of photovoltaics in the field (Green, 2005). Such features were necessary for the use of photovoltaics in remote outdoors locations. Modules were thus not necessarily developed with a view to mass deployment of photovoltaics.

However, the capacity of modules to be easily displaced without alteration had impact as soon as attempts were made to deploy photovoltaics on a larger scale. Photovoltaic modules are primarily defined by their ability to produce electricity, and the nature of the cells that they are made of matters only insofar as it affects this ability, which can be qualified and quantified in terms of conversion efficiency, cost, lifetime, etc… Because of the protection provided by modules, these qualities are not expected to change through the lifetime of a module. By stabilising and black-boxing the function of solar cells, modules thus facilitate standardization, mass market deployment, and circulation on a large scale. They can be plugged in a variety of photovoltaic systems, allowing for

[28] One of the definitions that the Oxford Dictionary gives of "emergent" is: "arising and existing only as a phenomenon of independent parts working together, and not predictable on the basis of their properties".

[29] As far as R&D is concerned, it remains predictable. As a researcher explained in an interview, "what will happen in the next 10 years is nearly written from a technological point of view. We already now, more or less, what may happen. Technologies have already been tested in laboratories quite a lot. […] I think that we already know all [the technologies] that we will see ten years from now. […] The technologies that will be mass technologies, dominant, will be those that we have today, at least in laboratories, with products, prototypes." (Interview 7).

experimentation and bricolage with photovoltaic systems by people with no particular expertise on how photovoltaic cells function.

Not only do photovoltaic modules contribute to making different types of photovoltaic cells comparable and substitutable; since they stabilise a function, they make it possible to focus on the electricity generated, and therefore also contribute to making photovoltaic electricity comparable and substitutable to electricity from other sources. In short, they contribute to the commodification of photovoltaic electricity. Modules alone are of course not sufficient to frame photovoltaic electricity as a product that can be traded on mass electricity markets, but they make it possible. Provided that modules can be connected to a balance of system that converts the direct current they generate into alternative current and ensures connection to the grid, their deployment as large-scale electricity generation devices is technically possible. Besides, a range of indicators and parameters has developed to include photovoltaic electricity into the calculative space of electricity markets. These make photovoltaic electricity as an economic good comparable to conventional electricity (in physical terms, apart from its specific pattern of availability, photovoltaic electricity cannot be distinguished from electricity from other sources).

Photovoltaic cells, modules and systems are thus characterised by indicators of their potentials, performance and reliability, and of the quality of the electricity they generate, as well as by a range of parameters that qualify them in terms of costs, competitiveness, maturity, and economic viability. Such indicators have largely contributed to the transformation of photovoltaic in at least two ways. First, they have made it commensurable with other sources of energy; and, by doing so, they have been instrumental in framing it as a promising carbon-neutral technology bound to reach commercial maturity in a not-so-distant future provided that markets are nurtured for it.[30]

They include learning curves tracing the evolution of the costs of photovoltaics according to the increase in cumulative production, the benchmark value of "grid parity", which indicates when photovoltaic applications become competitive with incumbent technologies on specific market segments, the levelized cost of electricity generation (LCOE), which makes different electricity generation technologies comparable in terms of long-term costs, evaluations of the potential of photovoltaics, and a large variety of scenarios and forecasts, for instance relative to cost evolution or to the amount of photovoltaic electricity in the electricity mix.

[30] This framing, of course, is contested, but the debate is usually in terms of determining when commercial maturity can be reached and to what extent photovoltaic is feasible and environmentally sound.

Box 1: Commonly used metrics characterising photovoltaic electricity

Price-per-watt of modules: "the most fundamental metric for considering the cost of PV", according to Bazilian et al. (2013, p. 331). Since modules were historically the most expensive part of photovoltaic systems, accounting for around 60% of total system costs (Wang et al., 2011 as cited in Bazilian et al., 2013), this used to be a good proxy of the capital cost of photovoltaics. However, the dramatic decrease in module prices has shifted the balance, making BOS cost the largest share of capital costs. These are more context-dependent and learning potentials are harder to define (Shum & Watanabe, 2008).
Learning rate: Relation between the evolution of prices and cumulative production. The average learning rate of photovoltaic modules over the last four decades has been of about 80%, meaning that the average selling prices of solar modules decreased by 20% for each doubling of production volume (Jäger-Waldau, 2013, p. 25).
Levelized cost of electricity (LCOE): The cost of an energy generating system over its lifetime, calculated as the per unit price at which the energy must be generated from source over lifetime to break even (Edenhofer et al., 2011, p. 25). It is used as a long-term guide to the competitiveness of technologies. For photovoltaics, it is subject to significant uncertainties, especially as it requires an estimate of the long-term performance of photovoltaic systems, which is very context specific (Bazilian et al., 2013). According to Bazilian et al. (2013, p. 332), the LCOE range for photovoltaics in the literature extends from 0.10 to 0.30 $/kWh for most contexts.
Grid parity: normally refers "to the LCOE of PV by comparison with alternative means of wholesale electricity provision" (Bazilian et al., 2013, p. 334), or, for small-scale photovoltaics, by comparison to the commercial price of electricity. It is a "cornerstone of PV-related messaging", and its occurrence is supposed to mark the commercial maturity of photovoltaic electricity, i.e. the moment when photovoltaic electricity no longer needs public support. However, given the diversity of photovoltaic electricity generation technologies, there is not one benchmark price that can be used to determine grid parity (the relevant value can be wholesale electricity price or residential retail prices depending on the type of photovoltaic installation). The value has thus been widely criticised (Bazilian et al., 2013; Yang, 2010; Interview 6), but remain widely used, as Bazilian et al. (2013, p. 335) have noted: "grid parity is now a largely out-dated concept stemming from an industry that has traditionally been used to being an 'underdog' of small scale and constantly fighting for a 'level playing field'."

In fact, most of the economic indicators that characterise photovoltaics are based on forecasts, potentials and projections, and therefore carry irreducible uncertainties. As a result, they frame photovoltaics as a promise, or, more accurately, as economic goods that are fit for *emerging* markets. The framing they provide is uncertain, contestable and multiple. They suggest that photovoltaic electricity may become an interesting economic product, but that to make it so, it has to be "artificially" constituted as interesting *before* the economic indicators turn green. This conception of photovoltaics as immature and prohibitively expensive remains widespread despite its recent dramatic cost reductions and massification, and despite the fact that some analysts have criticised it as outdated:

> “Despite the substantial drop in PV costs, many commentators continue to note that PV-generated power is prohibitively expensive unless heavily supported by subsidies or enhanced prices […]. Outdated numbers are still widely disemminated (sic) to governments, regulators and investors”. (Bazilian et al., 2013, p. 332)

In other words, the approach in terms of economic maturity of the technology frames the development of photovoltaics along this question: under what conditions, and with the help of which prosthetic devices if such conditions are not met, can it survive and thrive as an economic product?

By doing so, it also stresses that photovoltaic electricity cannot exist as a merchandise “by itself”. It draws attention to the *dispositifs* or *agencements* that make photovoltaics develop in certain forms. The modularity of photovoltaic technologies, and the development of a calculative apparatus that makes photovoltaic technologies and photovoltaic electricity able to compete on electricity markets have played their part in the recent emergence of grid-connected photovoltaics, but they alone cannot account for it. To understand how the playing field has levelled and enabled for the entry of photovoltaic electricity, one has to consider the devices and *dispositifs* that have triggered such transformation. Like Gomart is puzzled by the multiplicity of methadone, considering photovoltaics leaves one puzzled by how the same technology can turn from one used in niche market to one that can potentially be developed on a relatively large scale; like Gomart when studying methadone through the performance of its effects, to understand the multiplicity and transformations of photovoltaics, one has to turn to the *dispositifs* that make it happen. This is the objective of the next chapter.

Chapter 2

Defining feed-in tariffs for PV-generated electricity as political market *agencements*

> "The only people you're really ultimately 'free' with in this way are strangers and in this way my father was right about money and capitalism being equal to freedom, as buying or selling something doesn't obligate you to anything except what's written in the contract – although there's also the social contract, which is where the obligation to pay one's fair share of taxes comes in, and I think my father would have agreed with Mr. Glendenning's statement that 'Real freedom is freedom to obey the law'."
> David Foster Wallace—*The Pale King*

This dissertation started from the observation that, even though photovoltaic technologies have been around for a few decades, they have only recently expanded on a large scale and become contenders on electricity markets. How can we account for the recent transformations and proliferation of photovoltaics?

In the previous chapter, I have focused on the modularity of photovoltaic technologies as a partial explanation for the specificities of the deployment of photovoltaics. I have shown how the characteristics of photovoltaic modules enable photovoltaic technologies to circulate widely and quickly (because they are standardised) while taking a very large range of potential forms. However, the modularity of photovoltaics is not a novelty; it is an important dimension at play in the recent evolutions of photovoltaic technologies, markets and politics, but it alone cannot explain how they were triggered.

These evolutions have to do with the development of photovoltaics as a source of renewable energy, which has explicitly been driven by renewable energy support policies. In France as in many European countries, support for electricity from renewable energy sources (RES-E) is articulated around feed-in tariffs (FITs). FITs are peculiar insofar as they are both political and economic instruments. They are, in fact, policy devices designed to create and regulate markets to which the fulfilment of political objectives is delegated; in the case that this dissertation explores, the objective is the development of electricity from renewable energy sources, and in particular photovoltaics. How do feed-in tariffs work? How can their functioning and their effects be accounted for in their political *and* economic dimensions? What are their effects when they are used to support modular technologies such as photovoltaics?

The objective of this chapter is to describe feed-in tariffs and their interaction with photovoltaics as a set of modular technologies, as an emerging market and as a political issue. This analysis of feed-in tariffs entails a discussion of the notions of "market" and "politics" as they apply to the case of photovoltaics, and more generally of the relations between politics and economics in the case of a regulated, emerging market. In this chapter, I focus on the material and conceptual arrangement of feed-in tariffs for PV-generated electricity. To do so, I primarily rely on the notion of market *agencement*, which derives from that of *dispositif* introduced by Michel Foucault to describe sets of heterogeneous elements (objects, institutions, legal documents, administrative procedures, scientific statements, discourses, etc…) that perform a strategic function. The first section is mainly theoretical: it lays out the concepts that have informed my approach to feed-in tariffs for PV-generated electricity. In particular, I discuss the notion of market *agencements* in the light of STS work on marketisation and calculation. The second section describes feed-in tariffs for PV-generated electricity in terms of the framings they organise and discusses the modalities of their design and calibration. It leads me to define them as market *and* political *agencements* and to stress the tension between stability and change, constraint and letting go, which I argue is at the heart of this instrument.

Section 1 – Making photovoltaics happen

1.1. Understanding support to photovoltaics

1.1.1. Policy-dependent photovoltaic markets

A crucial aspect of the recent development and proliferation of photovoltaic markets, especially in Europe, is that it is policy-driven and policy-dependent. The role of policy support in pushing forward photovoltaic markets has been widely documented (e.g. Jäger-Waldau, 2011, 2012, 2013; EurObserv'ER, 2011; Debourdeau, 2011a, 2011b; Lipp, 2007). Support schemes for photovoltaics are key to describe photovoltaic markets as they are today, and to account for the changes that occurred during the last 15 to 20 years. The regions with highest installed photovoltaic capacities are indeed those in which support schemes have been in place for several years: Japan, some parts of the US (most notably California), European countries such as Germany, Spain, Italy, and to a lesser extent France. The Spanish case is particularly telling: when FITs were stopped in 2008, the rate of installations, which had just peaked, collapsed from one year to the next, dropping from 2.5 GWc of newly installed capacity in 2008 to 17 MWc in 2009 (EurObserv'ER, 2011). Policy support has enabled, driven and shaped the deployment of grid-connected photovoltaics.

Box 2: Photovoltaic support instruments

The instruments available to support photovoltaics are by and large the same as those used for all types of electricity generated from renewable energy sources. Aside from R&D support, which is a category of its own and not addressed extensively in this dissertation, most are market or economic instruments. The most widespread include feed-in tariffs (FIT), which guarantee a fixed price for photovoltaic electricity, feed-in premiums (FIP),[31] quota systems such as Renewable Portfolio Standards (RPS) in the US or Tradable Green Certificates (TGC) in Europe,[32] calls for tenders, tax credit, net metering,[33] and various types of investment subsidies, soft loans or development programmes (such as the German 1,000 and 100,000 solar roofs programmes). These instruments, which can vary widely in their design and implementation, are usually classified according to three main criteria: whether they are **regulatory** or **voluntary**, whether they are **investment focused** or **generation based**, and whether they are **price-driven** or **quantity-driven**. One of the most comprehensive classification is that proposed by Haas et al. (2007), which remains relevant today and which I reproduce in Table 5. Indeed, though instruments have been refined and sophisticated since then, the basic characteristics of instruments types and their numbers have not been altered significantly.

Photovoltaic support schemes combine several of these instruments, but they are often articulated around one or two core strategies; as chapter 3 will detail, the dominant instruments are feed-in tariffs, quotas, and calls for tenders.[34] As far as photovoltaic is concerned, feed-in tariffs appear to have been the most effective instrument in terms of installed capacity, and the European countries where photovoltaic electricity generation is the most developed have all, at some point, relied on a FIT scheme, even though it does not mean that such success should be entirely attributed to FITs (Dinica, 2008).

In France, support to photovoltaic electricity generation is articulated around feed-in tariffs and calls for tenders. Tax credits as well as low interest loans are also available for individual residential photovoltaic projects.

[31] Feed-in premiums are similar to feed-in tariffs insofar as they include a long-term purchase obligation; the difference lies in the fact that, instead of guaranteed a fixed price, they guarantee a fixed premium added to market price. The level of FIP thus fluctuates along with the market place for electricity, whereas FITs are completely independent from the electricity market.

[32] Under a quota system, an amount of electricity generated from renewable energy sources is set as an overall objective; RES-E producer obtain certificates that they can sell to those who fail to produce their share of electricity from renewable energy sources.

[33] Net-metering is the deduction of the electricity generated by a photovoltaic installation from the electricity bill of those who operate it, which in practice allows the owner of the photovoltaic system to use the electricity so generated and sell excess production to the grid (or purchase excess need).

[34] Literature abounds on diverse RES-E support schemes, see for instance Haas et al. 2004, 2007, 2011; Finon, 2008; Jäger-Waldau, 2011, 2012, 2013…

Table 5 Types of renewable energy support instruments, as described in Haas et al., 2007; Haas et al., 2011.

		Direct		Indirect
		Price-driven	**Quantity-driven**	
Regulatory	Investment focused	Investment subsidies Tax credits Low interest/soft loans	Tendering system for investment grant	Environmental taxes Simplification of authorisation procedures Connection charges, balancing costs
	Generation based	Feed-in tariffs Feed-in premiums	Tendering system for long-term contracts Renewable energy quotas (TGC, RPS)	Voluntary agreements
Voluntary	Investment focused	Shareholder programs Contribution programs		
	Generation based	Green tariffs		

Table 6 Examples of photovoltaic support schemes

Type of instrument	Examples of countries where implemented for photovoltaics
Feed-in tariffs	Germany (since 1990), Spain (until 2008), France, the UK (since 2010), China (since 2011)
Feed-in premiums	Italy, Spain (since 2008)
Quota systems (RPS, TGCs)	Several US States
Net metering	California
Calls for tender	France (for large-scale projects, since 2011)
Tax credit	France
Development programs	Germany (1,000 Solar roofs program, 10,000 Solar roofs program), Japan

Starting from policy-dependence as a defining feature of current grid-connected photovoltaic markets, one can understand these markets as *effects* of policy support. This means that the chief focus is not on what photovoltaic markets *are*, but on how they are provoked and enacted. Such a perspective directly draws on Gomart's approach to methadone (Gomart, 2002). To make sense of the multiplicity of methadone, Gomart shifted her attention from substance to effects, and, most importantly, to the set-ups or *dispositifs* that performs these effects. Defining methadone, she writes, "can only be done in reference to the specific *dispositifs* engaged each time in its achievement. It requires that one focus on the moment of indeterminacy when techniques are 'mediating actants'. It requires that one be attentive to the 'particulars' (the details, the devices): if we disregarded them, methadone would seem to be everywhere the same again" (Gomart, 2002, p. 126).

Though I deal with a very different object, the approach in terms of effects performed through *dispositifs* is helpful insofar as it frees from the necessity to start by defining the perimeter of photovoltaic's when analysing its emergence. It thus makes it possible to retain the modularity, flexibility and multiplicity of photovoltaics in the description, that is to say its potential for taking various forms and sizes, or rather not to reduce it too soon. The description of photovoltaic as something with specific, well-defined forms in given places at given times is the result of our analysis and exploration, not the beginning, as much as it is the result of the particular set-ups that enact it. It follows that I do not consider photovoltaics in general, but instead study the kinds of photovoltaics that emerged recently as a result of specific photovoltaic support schemes, and chiefly feed-in tariffs. In such a perspective, I seek to describe photovoltaic support schemes (and in particular those articulated around feed-in tariffs) as *dispositifs* that perform photovoltaic and photovoltaic markets.

1.1.2. Incentives for photovoltaic electricity generation as *dispositifs*

1.1.2.1. *Dispositifs*: origins, definition and implications

The notion of *dispositif* has spread widely in social science, with variations in meaning and implications, and for this reason it is worth briefly recalling where it comes from and how it has been used. It originates from the work of Michel Foucault, of which it is a structuring concept, and it is to Foucault's definition that Gomart explicitly refers (Gomart, 2002). However, as Callon remarks (Callon, 2013, p. 422), even though the concept cuts through Foucault's work, he only defined explicitly in a 1977 interview. Reflections upon the concept thus usually start from these few sentences:

> "un ensemble *résolument hétérogène* comportant des discours, des institutions, des aménagements architecturaux, des décisions réglementaires, des lois, des mesures administratives, des énoncés scientifiques, des propositions philosophiques, morales, philanthropiques ; bref, *du dit aussi bien que du non-dit*, voilà les éléments du dispositif. Le dispositif lui-même c'est le *réseau* qu'on établit entre ces éléments [...] par dispositif j'entends une sorte – disons – de formation qui à un moment donné, a eu pour fonction majeure de répondre à une urgence. Le dispositif a donc une *fonction stratégique dominante*... J'ai dit que le dispositif était de nature essentiellement stratégique, ce qui suppose qu'il s'agit d'une certaine manipulation de rapports de forces, d'une *intervention rationnelle et concertée dans ces rapports de forces*, soit pour les développer dans telle direction, soit pour les bloquer ou les stabiliser, les utiliser. Le dispositif, donc, est toujours inscrit dans un jeu de pouvoir, mais toujours lié aussi à une ou à des bornes de savoir qui en naissent, mais, tout autant, le conditionnent. C'est ça le dispositif: des *stratégies de rapports de forces supportant des types de savoirs, et supportés par eux* » (Foucault, 1994, p. 299 et sq., as cited in Agamben, 2007, p. 8 et sq., emphasis added).[35]

[35] "a resolutely heterogeneous set including discourses, institutions, architectural constructions, regulatory decisions, laws, administrative measures, scientific statements, philosophical, moral, philanthropic propositions; in short, said as well as unsaid, these are the elements that compose the *dispositif*. The *dispositif* itself is the network that is established between these elements […] by *dispositif* I mean a sort – let's say – of formation which dominant function at a given moment was to meet an emergency. The *dispositif* thus has a major strategic function… I said that the *dispositif* was of essentially strategic nature, which implies that it consists of a form of

As Agamben summed up, a *dispositif* according to Foucault has three distinctive characteristics: first, it is a **network of heterogeneous elements**, both discursive and non-discursive; second, it has a **strategic dimension** and, in that respect, it constitutes an intervention in power relations; and last, it results from a **combination of power and knowledge** (Agamben, 2007, p. 10).

The topics that Foucault studied have often led to stress the role of control and constraint played by *dispositifs* (Beuscart & Peerbaye, 2006, p. 5), but that should not lead to overlook their flexibility and potential for reconfiguration. Beuscart and Peerbaye indeed note that, even though Foucault's *dispositifs* are "specific historical formations resulting from the interplay of different heterogeneous elements", one of their characteristics is that they "survive the intentionality and the visions that presided to their set-up" (Beuscart & Peerbaye, 2006, p. 5, author's translation). *Dispositifs* are mobilised "to manage the effects that [they] have generated" (Beuscart & Peerbaye, 2006, p. 5, author's translation), or, as Foucault himself wrote:

> "chaque *effet* [engendré par le dispositif], positif ou négatif, voulu ou non voulu, vient entrer en résonance, ou en contradiction, avec les autres, et *appelle à une reprise, à un réajustement*, des éléments hétérogènes" (Foucault, 1994 [1977], p. 299, as cited in Beuscart & Peerbaye, 2006, p. 5, emphasis added).[36]

In fact, *dispositifs* can serve to **organise, govern and maintain power relations** by inscribing them in networks of heterogeneous elements, but they also **hold a potential for reconfiguration, creation and innovation**, and as such can constitute resources for action.

Deleuze pointed out this ambivalence as a key element of a "philosophy of *dispositifs*", describing it as a tension between "stratification" and "actualisation" (Deleuze, 1989). As he wrote in his discussion of the concept,

> "Tout dispositif se définit ainsi par sa teneur en nouveauté et créativité, qui marque en même temps sa capacité de se transformer, ou déjà de se fissurer au profit d'un dispositif de l'avenir, à moins au contraire d'un rabattu de force sur ses lignes les plus dures, les plus rigides ou solides" (Deleuze, 1989, p. 190).[37]

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manipulation of power relationships, of a rational a concerted intervention in these power relationships, either to develop them in one direction or to stop of stabilise them, to use them. The *dispositif*, then, is always inscribed in a game of power, but it is also always related to one or several bounds of knowledge that result from it but condition it just as much. That is what the *dipositif* is: power strategies that support types of knowledge, and supported by them." (author's translation)

[36] "each effect [engendered by the *dispositif*], either positive or negative, intended or unintended, resonates, or contradicts, the others, and calls for a reprise, a readjustments, of its heterogeneous elements." (author's translation)

[37] "Any *dispositif* is thus defined by its novelty and creativity content, which simultaneously marks its ability to change, or already to crack in favour of a future *dispositif*, unless on the contrary it folds down on its stiffer, more rigid or solid lines." (author's translation)

In this analysis, it follows that:

> "Les différentes lignes d'un dispositif se répartissent en deux groupes, lignes de stratification ou de sédimentation, lignes d'actualisation ou de créativité" (Deleuze, 1989, p. 192).[38]

Following Deleuze, Callon stresses this very tension as one of the most interesting features of *dispositifs* in his recent discussion of the term: he argues that *dispositifs* are one of the few notions able to capture regularity and innovation in one fell swoop:

> "Le dispositif est suffisamment flexible et variable (reconfigurable) pour expliquer les mécanismes de création, d'innovation, de changement, et rigide pour identifier ce qui est cadré dans ces dynamiques" (Callon, 2013, p. 423).[39]

This duality that the notion of *dispositif* seeks to capture will prove particularly instrumental to provide an alternative description of feed-in tariffs for PV-generated electricity, as I will explore in the second section of this chapter.

In their overview of the history of the concept of *dispositif,* Beuscart and Peerbaye note that it has been widely influential in recent development in social science, with increasing focus on the "indeterminacy of *dispositifs"* (Beuscart & Peerbaye, 2006, p. 5): *dispositifs* are now mostly referred to as "resources for action, in perpetual reconfiguration" (Beuscart & Peerbaye, 2006, p. 6).

The concept and more generally the approach that led Foucault to develop it have fed reflections on the status and role of objects in social science (Beuscart & Peerbaye, 2006, p. 8), and in particular informed the focus of STS and ANT research on the agency of objects and of assemblages of humans and non-human.[40] It has also been mobilised in several fields of social science research to analyse the role of material and discursive devices: organisation studies, new market sociology and public policy analysis have relied on it (Beuscart and Peerbaye, 2006, pp. 7-8). Lascoumes and Le Galès (2005, 2007) drew inspiration from Foucault's approach to develop a program for the study of the role of instrumentation in public policy change. Their objective in doing so is to move away from the functionalist orientation that dominates the study of public policy instruments and tends to consider as mere tools (Lascoumes & Le Galès, 2007, p. 3). In a perspective that echoes Foucault's definition of *dispositifs*, they propose to consider public policy instruments as devices that are "both technical and social, that organiz[e] specific social relations between the State and those [they are] addressed to, according to the representation and meaning [they carry]" (Lascoumes & Le Galès, 2007, p.4). It

[38] "The different lines of a *dispositif* fall in two categories, lines of stratification or sedimentations, lines of actualisation or creativity." (author's translation)

[39] "The *dispositif* is sufficiently flexible and variable (it can be reconfigured) to account for the mechanisms of creation, innovation and change, and sufficiently stiff to identify what is framed in such dynamics." (author's translation)

[40] Gomart's work provides an explicit example of this influence, which informs STS approaches more widely. Gomart explicitly refers to Foucault when using the term *dispositif* or set-up. She relies on it to refer to the details, the particulars in which specific effects of methadone are performed. The *dispositif* can thus be understood as a heterogeneous set of practices, knowledge, objects, discourses, experimental settings, etc. that "lets/makes happen" (Gomart, 2002, p. 99). In her account, she stresses the capacity of the setting of experiments to perform actions and effects: it is through the operation of experimental *dispositifs* that different effects of methadone are performed.

involves taking into account their material components as well as their effects and history.[41]

1.1.2.2. Applying the notion of *dispositif* to incentives for photovoltaic electricity generation

To what extent can this detour through the notion of *dispositif* inform an account of the policy-driven emergence of photovoltaics? Can it provide a framework for the description of the policy-market arrangements that triggered it?

Conceiving of incentives for photovoltaic electricity generation as *dispositifs* draws attention to several of their features that are easily lost when one considers instruments as stabilised black boxes.

(1) First, by **capturing the heterogeneity** of these instruments, it directs attention to what is *inside* the black box, that is not only to how instruments work but to *what* makes them work. The actual mechanics of feed-in tariffs involve many elements beside the logic that led to their design, and these can be articulated in many ways (and the articulation of which is often problematic, and at any rate cannot be taken for granted): regulatory texts that set their level; administrative procedures that give access to them; institutions, ministers, and civil servants responsible for their calibration, implementation and administration; the State, which guarantees the level of tariffs; purchase agreements and the monetary transfers they organise; spreadsheets to register and monitor the status of purchase agreement requests; discourses to justify their objectives and political legitimacy; cables and electric devices that connect photovoltaic installations to the grid; estimations of the price of photovoltaic installations; supply of photovoltaic systems; electricity users paying the levy that compensate the additional costs of FITs for electric utilities, etc… In other words, a FIT scheme connects and orchestrates the actions of several heterogeneous components, both discursive and non discursive, abstract and material, in a specific way.

(2) Second, the notion of *dispositif* highlights the **strategic dimension of feed-in tariffs**. As public policy instruments, it is clear that they are developed and put in place to address specific and strategic objectives. They are at least partly shaped by power relations. Further than that, they aim to affect current power relations and reconfigure them: support to photovoltaic elecricity and, more generally to renewable electricity, can be described as a way to tilt the balance between conventional and renewable electricity sources, and therefore to modify economic and political power relations in the electricity sector.

Instruments for the promotion of electricity from renewable energy sources in general, and feed-in tariffs for PV-generated electricity in particular, can thus be considered as government devices meant to configure and stabilise transformations of the electricity sector.

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[41] Though there are several parallels between my approach to feed-in tariffs for photovoltaic and Lascoumes & Le Galès's work, in particular in the focus on the material content and on the effects of a public policy instrument, I do not directly rely on it in this dissertation. That is why I do not develop the topic further in this chapter; a longer discussion of their theorisation of public policy instrumentation can be found in Annex 11.

(3) Still, and this is the third aspect that relying on *dispositifs* helps stress, they are meant to do so by **triggering specific actions and effects that will bring in novelty**. As a result, they carry a potential for reconfiguration, readjustment and creation (actualisation in Deleuze's terms). The fact that they result from a combination of heterogeneous elements that can be articulated in various manners adds to this potential for reconfiguration: a feed-in tariff is flexible, since its effects depend on the particulars of a heterogeneous network that can evolve and be assembled in more than one way. Therefore, it triggers and structures action but also has to take into account the effects of this action, either by limiting them or by transforming itself (Deleuze, 1989, p. 190). Indeed, feed-in tariffs for PV-generated electricity are put in place to create and support new markets that will spur innovation and modify the electricity sector, but they are also designed to direct and regulate these new markets, to keep them within the bounds of specific political objectives – for instance, increasing the share of electricity from renewable energy sources in the energy mix or providing a new outlet for jobs and industry.

Thus, feed-in tariffs for PV-generated electricity described as *dispositifs* are **networks articulating heterogeneous elements, developed with strategic political objectives, and aiming to re-structure specific power relations by triggering action**. They are further characterised by a **tension between structure and control** on the one hand, and **transformation and flexibility** on the other hand.

However, two aspects of feed-in tariffs for PV-generated electricity in particular deserve elaboration and analysis beyond what the notion of *dispositif* allows for.

(1) The first of these aspects stems from the fact that feed-in tariffs are policy instruments designed to **create and support markets**. As such, they inevitably articulate economic and political forms of agency and rationality, thus raising the issue of the definition of and interaction between economic and political modes of action. The original conception of *dispositifs* does include the issue of the distribution between and detours through different modes of action. As Callon, notes, addressing this issue in a new light is indeed an important contribution of Foucault's approach:

> "Un des effets recherchés de la notion de dispositif [...] est de nous libérer d'une vision du social qui établit de strictes distinctions entre des sphères, des champs, des sous-systèmes, des institutions, séparés et distincts. Il n'est évidemment pas question de remettre en cause l'idée qu'il existe des différences [...], mais plutôt de soutenir l'idée qu'on ne passe jamais directement d'un principe à un autre, d'un énoncé à un autre, d'une génération de machines à une autre, etc., *sans un détour qui fait intervenir et mobilise un ensemble d'éléments extérieur à la sphère d'activité concernée* (c'est pour cette raison qu'on parle d'hétérogénéité). Foucault ajouterait sans doute que ces détours ne se font pas au hasard, mais qu'ils obéissent à des modèles, à des régularités, en quoi consistent précisément les dispositifs et les réseaux qu'il évoque." (Callon, 2013, p. 423, emphasis added)[42]

[42] "one of the intended effects of the notion of *dispositif* […] is to free us from a vision of the social that establishes strict distinctions between spheres, fields, sub-systems, institutions that are separated and distinct. The point is obviously not to contest the idea that differences exist […], but rather to support the idea that one never moves directly from one principle to another, from one statement to another, from one technological generation to another, etc…, without a detour that involves and mobilises a set of elements that are exogenous to the realm of activity

Still, the notion of *dispositif* does not fully provide for the detailed description of these detours between different "spheres of activities", and it does not account for the (co-)constitution of distinct types of agencies and of their specificities. When Callon reviews the history of *dispositifs*, he regrets that this dimension (that is, agency and the detours through which it is constituted and distributed) has been overlooked in post-foucaldian developments on *dispositifs.* Studies of *dispositifs,* he argues, have tended to focus on the heterogeneity of assemblages[43] considered mainly as combinations or aggregations, thereby losing sight of the tensions and mutual constraints at play in *dispositifs* and of their ability to structure and direct action.[44]

(2) A second aspect of the policy-driven emergence of photovoltaic markets that the approach in terms of *dispositifs* does not fully capture has to do with the role of photovoltaic technology itself within the *dispositifs* it is caught up in. The material dimension of Foucault's *dispositifs* is clearly crucial to their comprehension, but it matters insofar as it contributes to the government of human beings. In other words, *dispositifs* are made of things but they are generally interpreted as designed to dispose of human beings, or at any rates beings, not things.

For instance, according to Agamben's discussion of the notion, a *dispositif* refers to "a set of praxis, knowledge, measures, institutions, the purpose of which is to manage, to govern, to control and to direct […] *the behaviours, gestures and thoughts of human beings*" (Agamben, 2007, p. 28, author's translation, emphasis added).[45] Agamben thus chooses to name a "*dispositif* all that has, in one way or another, the capacity to capture, to direct, to determine, to intercept, to mould, to control or to ensure the movements, behaviours, opinions and discourses *of living beings*" (Agamben, 2007, p. 31, author's translation, emphasis added).[46]

Yet, in the case of support to photovoltaics, as in numerous others that STS have put forward, the *dispositifs* at work are clearly not concerned with living beings only. Of course, as economic incentives and sets of regulations, feed-in tariffs for PV-generated electricity aim to direct the conduct of human beings, but they also explicitly seek to

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considered (hence the reference to heterogeneity). Foucault would probably add that these detours are not operated at random, but that they conform to models, to regularities, which are precisely what constitutes the *dispositifs* and the networks that he mentions." (author's translation).

[44] "... dès lors que se trouve implicitement distinguée la nature bipolaire du dispositif (réseau d'éléments hétérogènes qui disposent et dont disposent les êtres humains), la voie est préparée pour faire de l'assemblage d'éléments hétérogènes, en quoi consiste le dispositif, le résultat de pratiques purement combinatoires, comme si les relations entre les éléments (humains et non-humains) du dispositif n'étaient pas des relations de constitution mutuelle : le dispositif et ses réseaux de contraintes cèdent devant l'assemblage comme jeu de Lego." (Callon, 2013, p. 425).

[45] "Le lien qui rassemble tous ces termes est le renvoi à une économie, c'est-à-dire à un ensemble de praxis, de savoirs, de mesures, d'institutions dont le but est de gérer, de gouverner, de contrôler et d'orienter – en un sens qui se veut utile – les comportements, les gestes et les pensées des hommes."

[46] "tout ce qui a, d'une manière ou d'une autre, la capacité de capturer, d'orienter, de déterminer, d'intercepter, de modeler, de contrôler et d'assurer les gestes, les conduites, les opinions et les discours des êtres vivants."

govern the development of photovoltaic technologies. They are designed to accelerate and regulate their deployment, to influence their innovation trajectories, to mould their shapes and sizes, to frame their economic characteristics, etc. Further than that, I will attempt to show that photovoltaic technologies are *active* within these *dispositifs*. They cannot be considered as passive and predictable entities that feed-in tariffs will simply help to deploy on a larger scale. The way they react to regulation has to be taken into account: it contributes to the production of new knowledge, for instance by making visible differences in exposition to the sun (cf. Chapter 5); it potentially alters existing power relations (or their expected evolutions), as when the uncontrolled proliferation of photovoltaic installations damaged the legitimacy of representatives of the French photovoltaic sectors (cf. Chapter 4); and, more broadly, it generates unintended consequences that call for the reconfiguration of support schemes.

1.2. From *dispostifs* to market *agencements*

1.1.2. Socio-technical *agencements*

In order to retain the conceptual richness of the notion of *dispostif* while accounting in details for the economic and political nature of feed-in tariffs, and for the relationship between feed-in tariffs and photovoltaic technologies, I propose to rely on the notion of socio-technical *agencement.* The use of the term *agencement* originates from the work of Deleuze and Guattari, and directly derives from Foucault's *dispositifs,* which it revisits and specifies (Deleuze & Guattari, 1980). It has been deployed in ANT literature on markets and the performativity of economics, and in particular in the works of Michel Callon, who uses it as a central concept for theorising market dynamics. Here, I will not directly discuss Deleuze and Guattari's definition, but will focus on Callon's interpretation of it (Callon, 2013).

What *agencements* add to *dispositifs*, Callon argues, is the ability to render and analyse agency as heterogeneous and distributed. This aspect was included in the concept of *agencement* as introduced by Deleuze and Guattari, but it has been largely lost in its translation as "*assemblage*" or sometimes "*arrangement*"[47] in English (Callon, 2013, p. 426). Such terms emphasize the idea of aggregation that is indeed at play in both *dispositifs* and *agencements*, but according to Callon they fail to render the originality of *agencements* as an approach to action.

Contrary to "*dispositif*", "*assemblage*" or "*arrangement*", the term "*agencement"* carries a dual meaning. First, it conveys the idea of a **careful adjustment of heterogeneous components** – in that respect, it is very close to the word "*arrangement*". But its shared root with the word "agency" stresses the **active dimension** that it implies. *Agencements,* "are arrangements endowed with the capacity of acting in different ways, depending on their configuration" (Caliskan & Callon, 2010, p. 9). Then, by referring both to adjustment and agency, the term *agencement* points to sets of heterogeneous entities that **act because they are adjusted together**. This justifies going back back to the original French term: the notion of *agencement* can provide "an answer to the

[47] Thourghout this dissertation, I use the term "arrangement" in the basic sense of "things put together"; in such instances, it carries no theoretical meaning.

issue of the origins of action" – an issue that *arrangement, dispositifs* or *assemblages* do not address explicitly (Callon, 2013, p. 428).

The term *agencement* thus implies a very specific interpretation of action, which echoes the redefinition of agency by Actor-network theory that I reviewed in chapter 1. For ANT, agency involves both the capacity to act and to give meaning to action (Callon, 2005, p. 4); it is relational, distributed among heterogeneous entities, uncertain and problematic, and always potentially overflowing.[48]

The notion of socio-technical *agencements* as a theoretical device to investigate the making of agency is in line with this perspective. Three distinctive features characterize the conception of action that *agencements* propose to capture: a view of agency as **heterogeneous and distributed**; an equal attention to **material dimensions and to knowledge and statement**s; and the **dynamic evolution** of agencies that are made and always changing.

First, *agencements* act as heterogeneous combinations "of human beings and technical devices that are caught up in a dynamic configuration" (Callon, 2004, p. 121). Agency is distributed and deployed in heterogeneous configurations where it is impossible to definitely separate humans from non-humans. Agency cannot be attributed to either humans or techniques, it is the result of their mutual adjustment in *agencements*. To stress this feature, Callon gives the example of an airline pilot. Even though the pilot is considered as responsible for steering the plane and is able to set goals and chose courses of action, she could not do so in isolation. The action of steering the plane relies on, or rather is distributed among a set of heterogeneous entities, including "air-traffic controllers strips, international regulations, radars, gyroscopes, control levers, pilots and co-pilots, landing strips, international regulations, etc." that cannot be considered independently from one another (Callon, 2008, p. 35).

Second, the notion stresses the importance of **materiality and practices** as much as that of **meanings, knowledge and discourses**. *Agencements* (like *dispositifs*) include both material and immaterial, non-discursive and discursive components. The statements, theories and models about an *agencement* are also part of it, since they contribute to its functioning. The study of *agencements* thus involves an analysis not only of their material and formal arrangement, but also of the construction of their meanings. Then, and this echoes one of the key guidelines of ANT, there is no need to resort to contexts when accounting for an *agencement*: everything that takes part in configuring and performing it must be included in its description. Or, as Callon points out:

> "[…] there is nothing left outside *agencements*: there is no need for further explanation, because the construction of its meaning is part of an *agencement*. A socio-technical *agencement* includes the statement[s] pointing to it, and it is because the former includes the latter that the *agencement* acts in line with the statement, just as the operating instructions are part of the device and participate in making it work." (Callon, 2006, p. 13)

[48] "Action, including its reflexive dimension that produces meaning, takes place in hybrid collectives comprising human beings as well as material and technical devices, texts, etc." (Callon, 2005, p. 4)

The notion indeed points to the mutual constitution and formatting of agencies as well as to performativity, that is to the fact that the construction of meaning, statement and theories itself contributes to the making of agencies. Theories and statements about a particular *agencement* are part of it and contribute to framing the agency it constitutes. The notion thus "stresses that the agencies taking part in the action are formatted and that this formatting concerns their capacities as agencies. It then emphasises that this formatting can result from a set of practices whose explicit purpose is to conceive and implement them.

This focus on the formatting of agencies clearly distinguishes Callon's socio-technical *agencements* from *dispositifs* or assemblages. It provides a way to account for both the structuring character of *agencements* and the dynamics of design that shape them. *Agencements* can be solid enough to frame action, but they retain a potential for instability, reconfiguration and innovation.

Because *agencements* are not given but always caught up between the structures they frame and the dynamics that carry them away, the making of agencies can be approached as "an infinite and never-ending project" (Caliskan & Callon, 2010, p. 10). *Agencements,* and hence the agencies that they configure, can change in size, in power and in nature; they can sediment into lasting structures or be constantly challenged, disrupted and overflowed. As a result, a specific *agencement* can only be apprehended if its dynamics and history are taken into account.

The notion of *agencement* is thus complex enough to **account for the heterogeneity and distributed character of action, for the intermingling of materials and statements that are necessary to produce effects and meanings, and for the tension between structure and innovation, stability and disruption through which agencies evolve**. As the study of *agencements* implies a focus on the making of agencies, it provides a **means of inquiry into the modalities of action**, and specifically into the detours through which action is configured and performed.[49] In particular, it can inform an analysis of feed-in tariffs for PV-generated electricity as **economic and political devices that trigger and configure action along specific lines that direct it but can always potentially carry it away**.

1.2.2. Market *agencements*

1.2.2.1. A focus on the *agencement* of market transactions

Following Andrew Barry's proposal to study socio-technical arrangements to account for the fact that "effects emerge from a combination of persons and materials" and Callon's discussion of it (Barry, 2001, p. 11; Callon, 2004), the notion of socio-technical *agencement* has developed into a theoretical device for the study of markets. The definition and interpretation of the notion of "market socio-technical *agencement"* has been refined throughout several articles developing an ANT approach to the study of markets and market devices (Callon, 2004, 2007, 2008, 2013; Callon et al., 2007;

[49] To specify the modalities of action, Barry (2001) and Callon (2004, 2013) rely on the notion of diagram, originally suggested by Deleuze. A diagram is "that which profiles in a way the action of the *agencement*" (Callon, 2013, p. 428, author's translation).

Caliskan & Callon, 2009, 2010; Muniesa & Callon, 2007; Muniesa, 2003). These articles have developed into a theory of "***market agencements***", which Callon has defined as specific *agencements* that frame economic agencies, goods and transactions (Callon, 2013). To an extent, the notion can still be considered to be in development: parts of its definition are stabilised, others have undergone alterations and reinterpretations in the light of new research. As a result, it is difficult to provide a thorough, immutable definition of it. My objective here is to review the uses of the term in recent developments in market sociology so as to highlight some key aspects of the concept, and in particular to stress what it brings to the analysis of market-making processes.

A **market *agencement*** is an *agencement* that **shapes and makes possible specific forms of economic actions** and thus contributes to **"enacting a specific version of what it means to be economic"** (Callon, Millo & Muniesa, 2007, p.4). The kind of economic action that market *agencement* format and allow is one **centred on transactions involving monetary compensation**. Market *agencements* are thus involved in processes of marketisation or market-making, and their good functioning and stabilisation is both a condition and an outcome of these processes.

The notion allows for a focus on two dimensions that have been of particular interest to ANT-inspired studies of the economy. First, as outlined in the previous section, *agencements* mobilise diverse forms of knowledge as well as material entities. But, since *agencements* configure specific actions and perform effects, the study of market *agencement* also directs attention to the *process* of enacting markets, that is to the **devices, theories, actions and procedure that *make* things and people fit for market exchanges**. It can thus contribute to the understanding of processes of marketisation as well as to the analysis of the performativity of economics (Callon, 1998; MacKenzie, Muniesa & Siu, 2007) – two issues at the heart of ANT approaches to markets.[50] Indeed, as Caliskan and Callon state:

> "First and foremost, the analysis of [market socio-technical *agencements*] highlights the role of knowledge – whether academic or not, professional or amateur, explicit or tacit – as well as of the materialities that are mobilized in the marketization process. Knowledge and materialities participate in the design, elaboration, experimentation, change, maintenance, extension and operation of *agencements*. Inquiring into the role of knowledge and materialities in the elaboration of markets enables us to articulate a connection between the study of marketization and the performativity programme. More precisely, we can draw a link between marketization and the co-performation of [market socio-technical *agencements*] by economics" (Caliskan & Callon, 2010, p. 23).

The notion of market *agencement* also serves to characterise the specificities of market actions. In what ways do the actions coordinated by markets differ from other activities? Under what conditions do markets operate? What is specific about market agencies and devices?

[50] For an analysis of the interdependence of economic theory and the (material, procedural, conceptual, symbolical, etc.) framing of agents and goods through which markets are made, see Holm's study of individual transferable quotas (ITQs) in Norwegian fisheries (Holm, 2007). Holm provides a particularly convincing account of the role of materialities and knowledge in both the performativity of economics *and* the making of market. Though he does not use the term, his description of ITQs and "cyborg fish" as complex and heterogeneous outcomes of these two processes (performativity and marketisation) can be read as an account of the constitution of market *agencements*.

1.2.2.2. The organisation of market framings

Agencements configure collective action by **framing** it. As long as they are maintained, the framings that an *agencement* organises produce strong constraints that direct actions along certain lines (Callon, 2013, p. 428-9). What are the framings that are specific to market *agencements*?

Building upon a strand of work on market-making (Thomas, 1991; Guesnerie, 1996; Callon, 1998, 1999, 2005, 2007; Caliskan & Callon, 2009, 2010; Callon, Millo & Muniesa, 2007; MacKenzie, Muniesa & Siu, 2007), Callon has defined market *agencements* as "directed towards the realisation of transactions in which the entanglement of goods and agencies ends in a transfer of property involving a monetary compensation" (Callon, 2013, p. 373-374).[51] Market activities involve a series of interdependent framings that permit the valuation, calculation and transfer of goods by and between agents. These are structured by market *agencements*:

> "Les agencements marchands ne se contentent pas de structurer, autour de biens déjà-là, la confrontation entre des offres et des demandes dont la genèse n'est pas interrogée. La charge principale qui leur incombe est d'organiser l'émergence conjointe et progressive des biens, de leurs vendeurs et de leurs acheteurs. Le processus qui aboutit (lorsqu'il réussit) au cadrage de cette triade et de la transaction qu'elle instaure passe, on l'a vu, par les multiples opérations de valuation qui assurent l'ajustement progressif des différents éléments qui la composent. Pas d'agencements marchands sans organisation stricte de ce processus, c'est-à-dire sans cadrage précis des sites de *valuation* et de leur coordination." (Callon, 2013, p. 367)[52]

These framings have been characterised in several articles (Callon, 1998; Muniesa & Callon, 2007; Caliskan & Callon, 2010; Callon, 2013). Their exact definitions and delimitation vary slightly, but they point to a relatively stable set of related operations. These operations, or framings, when they succeed, organise:

- the progressive emergence and mutual adjustment of passive, disentangled goods that can be valued and exchanged on the one hand, and of calculating agencies that can value and exchange them on the other;
- the **encounters** of goods, buyers and sellers and the **coordination** of sites of valuations;
- the stimulation and maintaining of *attachments* and affects that drive exchanges;
- the **calculation and formulation of prices** that enable transactions to happen and parties in exchanges to leave quits.

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[51] "orienté vers l'accomplissement de transactions dans lesquelles l'attachement des biens et des agences se conclut par un transfert de propriété en échange d'une compensation monétaire." (Callon, 2013, p. 373-4)

[52] "Market *agencements* do not only structure, around goods that are already-there, the confrontation of supplies and demands which genesis is not questioned. Their main task is to organise the joint and gradual emergence of goods, of their traders and of their purchasers. The process that (when it succeeds) leads to the framing of this triad and of the transaction that it establishes, we have shown, goes through multiple operations of valuation that ensure the gradual adjustment of the various elements that constitute it. No market *agencement*s exist without a strict organisation of this process, that is to say without a precise framing of the sites of *valuation* and of their coordination." (author's translation)

Table 7 Types of market framings

Muniesa & Callon, 2007	**Caliskan & Callon, 2010**	**Callon, 2013**
"Calculable" goods	Pacifying goods	'Passivation' of goods
Calculative agencies	Marketizing agencies	Activation of calculative agencies
Calculated encounters (algorithmic configurations of the market)	Market encounters	Organisation of market encounters
	Market design and maintenance	Affectio mercatus (market attachements)
	Price-setting	Price formulation

The term "framing" deserves elaboration. In the ANT approach to the study of markets, it does not highlight structuring effects so much as their precariousness and fragility. Callon initially introduced "framing" as a notion applicable to the study of markets in his conclusion to *The Laws of the Market* (Callon, 1998). Framing, Callon stressed, is necessary to the functioning of markets, but it is never complete. As in Goffman's definition (1971), to which Callon referred in his 1998 piece, the framing process "puts the outside world in brackets but does not abolish all links with it"; indeed, Callon stresses, "for Goffman, framing would be inexplicable if there was not a network of connections with the outside world" (Callon, 1998, p. 249).

Thus, framing is the exception rather than the norm; it is a rare and expensive outcome that always carries with it the potential for ***overflowing***, that is for its own disruption. Framings are effective *because* they are incomplete: their point is precisely to create the conditions for specific actions by "extricat[ing] the agents concerned from [their] network of interactions and push them onto a clearly demarcated 'stage' which has been specially prepared and fitted out" (Callon, 1998, p. 253).

As discussed above, the notion of *agencement* conveys a similar ambivalence, since an *agencement* is subject to reconfigurations triggered by its own effects.

Market *agencements* **organise market transactions through a series of interdependent framing operations** that make **valuation, calculation and exchange** possible. But these **framings are never definitive** – as the importance of the co-profiling and mutual, iterative adjustments of goods and agencies suggests. They can always be challenged or disproved, and, at any rate, are **subjected to reconfigurations and evolutions**.[53]

As Callon writes,

> "comme tout cadrage est sujet à débordement (Callon, 1999), cette action collective n'arrête pas de produire des écarts, et donc d'être reprise et transformée. C'est la manière la plus simple me semble-t-il de répondre à la question du changement. Un agencement marchand ne peut éponger les débordements provoqués par ses propres cadrages. Qu'il tende à maintenir son caractère marchand ou qu'au contraire il s'efforce de le perdre, il

[53] "the market is not simply expanding, but rather continuously emerging and re-emerging, and […] its consolidation requires constant and substantial investments." (Callon, 1998, p. 245)

doit évoluer. Ces débordements font écho à ce que Deleuze appelle les lignes de fuite des dispositifs (Deleuze, 1989)" (Callon, 2013, p. 428-9).[54]

1.2.2.3. Calculating and disentangling

In this approach to markets, framings are closely related to two other operations: ***calculation*** and ***disentanglement***. The functioning of markets can be summed up as depending on the success of these three interwoven processes.

Framing, I outlined above, is "the tracing of a boundary between relationships and events which are internalized and included in a decision or, by contrast, externalized and excluded from it" (Callon, 1998, p. 15). It thus refers to any operation that **demarcates what is to be taken into account from what is to be ignored**. As far as market activities are concerned, the ultimate end of framing is the exchange of goods between agents involving monetary compensation (Callon, 2013). Markets, in this perspective, can be described as collective calculative devices (Muniesa & Callon, 2007).

In large part, then, **market framings mean to permit and organise the calculative operations through which market transactions are performed**: those that lead **agents to engage in transactions**; those involved in the **negotiation of the terms of the transactions** (in particular, the formulation of prices); and those that **settle the deal** and enable agents to be quits.

1.2.2.3.1. Calculation

Accounting for these operations implies a partial redefinition of ***calculation***, which is detailed in Muniesa & Callon (2002). Following Cochoy's work on "*qualculation*" (Cochoy, 2002), calculations are understood as involving **both quantitative and qualitative assessments** that make it possible to list and compare entities.

From Muniesa and Callon's perspective, calculation involves **three sets of material and conceptual operations** (Muniesa & Callon, 2002). First, a **space for comparison** must be delimited, that is to say that possible options must be "extracted" and formatted in a single space, either material or immaterial (or both). Second, the elements thus grouped need to be **positioned in relation to each other** through a process of **classification and qualification** that makes them "simultaneously comparable and different". Last, these operations must lead to the extraction of a result able to circulate outside of the space of calculation. At the outcome of this process, the product is thus "objectified and singularised: objectified, because the properties that qualify it by defining it have been gradually stabilised; and singularised, because these properties have been determined so as to fit the customer's needs as well as possible"

[54] "as any framing is subject to overflowing (Callon, 1999), this collective action never ceases to deviate, and so to be corrected and transformed. It seems to me that it is the simplest manner to address the issue of change. A market *agencement* cannot absorb the overflowings triggered by its own framings. Whether it tends to maintain its market character or on the contrary to endeavour to lose it, it must evolve. These oveflowings echo what Deleuze calls the convergence lines [*lignes de fuite*] of *dispositifs*." (author's translation)

(Muniesa & Callon, 2002, p. 205, author's translation).[55] These operations are carried out by **calculative agencies**, who are co-constituted and equipped in the process. Calculative capacities are unevenly distributed. Though these inequalities are never definitive's, they play a crucial part in the negotiation of transactions.

In other words, **the achievement of a transaction is the outcome of the co-profiling and mutual adjustment of calculable goods and calculative agencies**. Throughout this process of mutual adjustment, the qualities of the good to be exchanged are stabilised in a way that **simultaneously makes it comparable** to others and **singles it out**. The qualification of a good implies that those of its qualities to be taken into account are determined, stabilised and assessed in terms that make it similar, but not identical, to others and, at the same time, interesting for and suited to the potential purchaser.

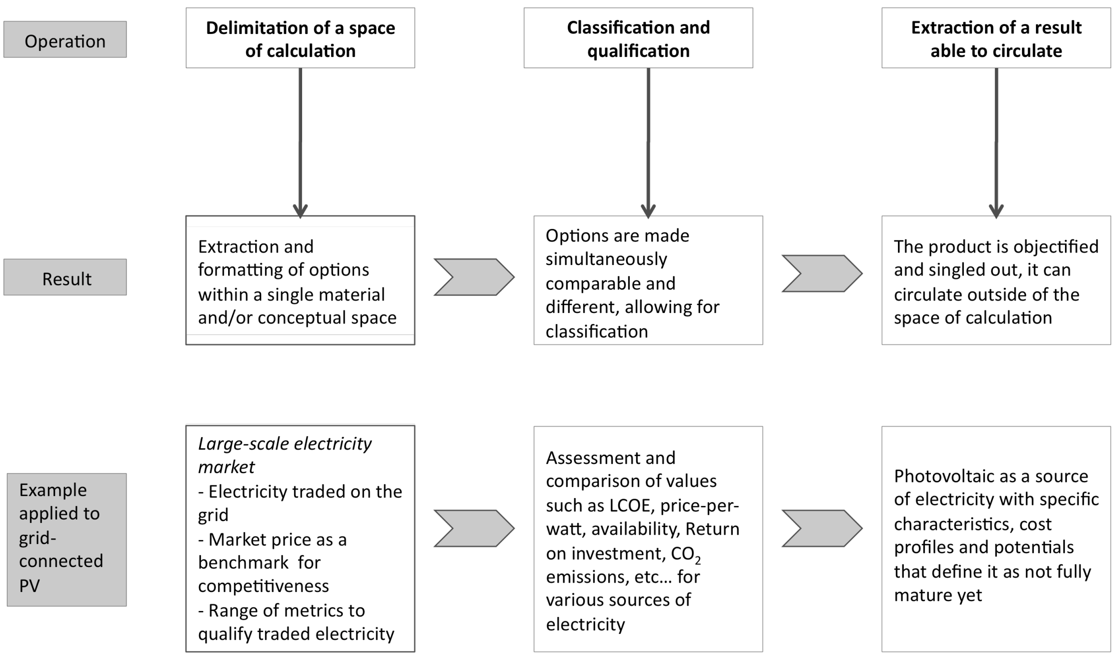

Figure 7 The process of calculation, as defined in Muniesa & Callon (2002) and applied to the case of grid-connected photovoltaics

[55] "Le produit est ainsi objectivé et singularisé: objectivé parce que les propriétés qui le qualifient en le définissant ont été progressivement stabilisées; et singularisé parce que ces propriétés ont été déterminées de façon à s'ajuster aussi bien que possible aux besoins du client."

1.2.2.3.2. Disentanglements and re-entanglements

In this process of qualification and singularisation, the good is thus disentangled from some of the relationships that it was caught up in, while being prepared for acquisition by a customer, that is, for re-entanglement into the world of its future owner. ***Disentanglement*** and ***re-entanglement*** are crucial operations for market transactions to take place. If goods were not disentangled *and* subsequently re-entangled differently, calculations would be impossible and transactions could never be settled.

In the first place, disentanglement **cuts the ties that would complicate the transactions if they were taken into account**, thereby making calculation manageable.

> "If calculations are to be performed and completed, Callon writes, the agents and goods involved in these calculations must be disentangled and framed." (Callon, 1998, p. 16)

Disentanglement is necessary to turn goods into merchandises or commodities that can circulate from hands to hands: circulation would not be possible if the infinite and heterogeneous networks of relations into which a thing is enmeshed were to be taken into account when calculating their exchange value. Circulation and valuation imply a form of alienation of things to be exchanged, as transactions could never be fully settled if goods carried with them the nets of all their previous ties, so some of these need to be severed. This is the argument developed by Thomas, upon which Callon originally based its definition of disentanglement.

> "Commodities are here understood as objects, persons, or elements of persons which are placed in a context in which they have exchange value and can be alienated. The alienation of a thing is its dissociation from producers, former users, or prior context." (Thomas, 1991, p. 39, as quoted in Callon, 1998, p. 19)

Disentanglement also involves, to an extent, a re-formatting (or framing) of things. The definition of their exchange value implies that the characteristics that define this value are stabilised and standardised – that is, the thing needs to be labelled in a way that makes it calculable and enables its circulation through various hands and contexts. Materiality and the devising of conceptual and metrological devices play a ,crucial role in the process, as seminal works on the materiality of markets have shown in cases as varied as the Chicago grain market (Cronon, 1991), Norwegian fisheries (Holm, 2007), stock exchange markets (Muniesa, 2003; Preda, 2006) or carbon markets (MacKenzie, 2009), among others.

Still, disentanglement only accounts for one part of market transactions. To be exchanged, good needs to be de-appropriated, but also re-appropriated. It must leave the world of the seller to be incorporated into this of the buyer. **Re-entanglement, that is, the creation of new ties that attach a good to its buyer**, is as crucial an operation as disentanglement, and one in facts implies the other. As Callon summarises:

> "The existence of a market implies the circulation of merchandise, that is, the existence of goods transformed into things that can be passed from hand to hand. This circulation is simultaneously a process of production and qualification that transforms products and in so doing qualifies them in such a way that they are attached to users by entering their worlds and becoming parts of it" (Callon, 2005, p. 5).

Disentanglement and re-entanglement, which **specify the dynamics at play in the framing and calculation of market transactions**, thus serve to render the **transformations that are necessary** for a specific thing to (1) be **made exchangeable** in a market transaction and (2) **effectively change hands**.

Section 2 – Overflowed by design: the mechanics of feed-in tariffs for PV-generated electricity

In the first section of this chapter, I have shown how the notion of socio-technical *agencement* draws attention to the agency of *dispositifs*, that is to their capacity to produce differences and to give meaning to their actions and effects. It thus provides a conceptual basis to explore feed-in tariffs for PV-generated electricity in terms of the actions and transactions that they provoke, frame, trigger and/or unleash. In other words, it makes it possible to consider feed-in tariffs for PV-generated electricity in the light of their intended and unintended effects. Feed-in tariffs for PV-generated electricity are designed to direct action by triggering and controlling specific effects; some of their effects, however, overflow the intentions articulated within the device, carry it away and reconfigure it. As shown above, the concept of *agencement* precisely renders this tension and interdependence between control and instability. In the case of photovoltaic support, this tension is all the more difficult to manage and account for that feed-in tariffs are to an extent meant to unleash processes that are beyond their control; they are, arguably, *overflowed by design*, but there is a limit to the amount of overflowing that can be managed and tolerated, as this dissertation will attempt to show.

As detailed above, market *agencements* are specific forms of socio-technical *agencements* that frame and make possible market transactions. The notion has been used to investigate processes of marketisation, and it appears relevant here, since feed-in tariffs for PV-generated electricity are designed to support and sustain the creation of markets for photovoltaic electricity and technologies.

In this section, I describe French feed-in tariffs for PV-generated electricity as market *agencements*. I mainly consider the transactions that are directly organised by feed-in tariffs and do not describe in details the other transactions involving photovoltaic electricity or photovoltaic technologies (such as the trade in photovoltaic modules or the installation of photovoltaic systems for onsite use). [56] In the light of the definition of market *agencement* provided in the previous section, this has three analytical implications. First, it involves a **description and analysis of the way in feed-in tariffs for PV-generated electricity trigger and frame market transactions** that

[56] It remains unclear in Callon's definition of *agencements* whether they refer to the devices that organise transactions or to the operations of transactions themselves (which often involves several devices and agencies), and how they relate to markets (are they meant to replace the concept of 'market' altogether by drawing attention on specific, local transactions, or do they just take part in the organisation of markets?). In this dissertation, I will use the term "photovoltaic market(s)" when referring to the wide variety of commercial exchanges that participate in the emergence of photovoltaic as a whole. I consider feed-in tariffs *agencements* as pertaining to one specific kind of these many transactions involving photovoltaic.

would not take place without them. Second, it requires **attention to their dynamics and evolution**, and especially to the re-adjustments and re-configuration that they are subjected to. Last, it calls for an account of the capacity of feed-in tariffs for PV-generated electricity to **simultaneously release and constrain action**.

However, this section will also show two features of feed-in tariffs for PV-generated electricity distinguish them from "standard" market *agencements*: the effects of feed-in tariffs are not limited to the organisation of bilateral market transactions.

First, feed-in tariffs for PV-generated electricity as market *agencements* are indeed **designed to have effects beyond the mere constitution and organisation of new markets**. They are expected to produce dynamic effects: accelerating innovation, inducing learning-by-doing and thus provoking a decrease in the cost of photovoltaic systems and of the electricity they generate. They thus aim to "activate" certain properties of photovoltaic technologies: for instance their potential for innovation-induced cost reductions, or for "greening" electricity production. Thereby, they are expected to trigger modifications in the characteristics of photovoltaics: cost reductions, innovations in photovoltaic system design and development of emergent forms of photovoltaic technologies, enhanced architectural integration of photovoltaic installations, new business models, etc.... This aspect of feed-in tariffs gains saliency when considered in relation to the modularity of photovoltaic technologies, because it means that feed-in tariffs act on photovoltaic technologies on two distinct levels. Not only are they meant to trigger the **deployment and multiplication of photovoltaic systems as passive interfaces** that matter only insofar as they produce electricity from sunlight; they also count on the multiple and unpredictable innovations and combinations that photovoltaic technologies make possible, thereby **activating them as mediators**.

Second, the transactions that feed-in tariffs make possible and frame are not bilateral but, one could say, trilateral: they **involve a third party, the State**, which sets the terms of the transaction without actually taking part in it, thereby acting as a peculiar kind of broker as well as an arbiter. As can be expected, the crucial role played by the State in FIT-driven transactions introduces a considerable asymmetry that can call into question the "market" character of FIT.[57] It entails that feed-in tariffs for PV-generated electricity are not only market *agencements*: they are also political *agencements*. As I will explore in the second half of this section, they rely on political objectives, negotiations and compromises *and* have political effects that trigger political processes.

[57] Indeed, the legitimacy of feed-in tariffs as market instruments has been called into question, especially by the European Commission, precisely because FITs rely on State regulation to be made operational. This issue will be explored in more details in chapter 3.

2.1. A description of feed-in tariffs for PV-generated electricity as market *agencements*

2.1.1. Transactions of PV-generated electricity as framed by feed-in tariffs

Then, how do feed-in tariffs for PV-generated electricity operate as market *agencements*? What are the operations that characterise FIT-driven transactions of photovoltaic electricity?

If we consider their most generic characteristics, feed-in tariff schemes[58] can be defined as systems that "offer guaranteed prices for fixed periods of time for electricity produced from renewable energy sources" (Couture & Gagnon, 20, p. 955). They constitute regulatory arrangements for "feeding" electricity from renewable energy sources in electricity grids and markets, and thus provide one way to enable the integration of previously unaccounted for sources of electricity into pre-existing market *agencements* that would otherwise not accommodate them.

To do so, FIT schemes articulate three elements whose main effect is to secure investment in renewable electricity generation capacity: a **purchase obligation**, a **fixed price**, and a **fixed period of time** over which the fixed price is guaranteed (Fig. 8; Jacobs, 2010, p. 28). They are completed by a mechanism to compensate for the extra-costs induced by the purchase obligation and the fixed rate (most commonly in the form of a levy on electricity consumption). Each of these elements rely on a heterogeneous set of material, textual, calculative and procedural elements that can be arranged in various ways, which is why actual FIT schemes can differ widely from one another.

At any rate, FIT result in an "almost risk-free contract" from the perspective of the producer of electricity from renewable energy sources (Mitchell et al., 2011, p. 50), who is protected from competition on the electricity market by three strong guarantees backed by the State and thus has nearly full visibility over future returns on investments.

[58] By using the term "FIT scheme", I refer not just to feed-in tariffs per se, but also to the sets of additional regulations, procedures, measurement devices, etc. that enable their good functioning.

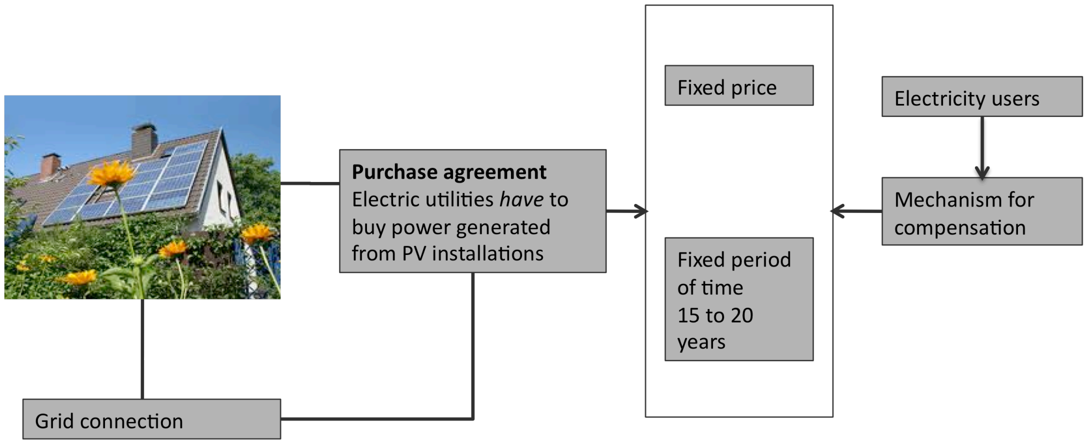

Figure 8 The basic structure of a feed-in tariff scheme

FIT schemes are thus flexible in that they can be arranged in various ways, but, as market *agencements*, they are rather constraining since they settle many of the calculations that agents would normally be expected to negotiate. Which operations of framing do they organise and how?[59]

Feed-in tariffs for PV-generated electricity first organise transactions by **qualifying photovoltaic electricity as an exchangeable good** that can transit through electricity grids and be traded on the electricity market (1).

This qualification takes into account the specificities of the purchasers, i.e. electricity retailers and grid operators. It is all the more important that the qualification of photovoltaic electricity suits their needs that FIT schemes determine the set of its purchasers and arrange the terms and conditions of the transactions in a binding way. The framing of the good to be exchanged is thus closely related to that of the purchasing agencies, the market encounters and the formulation of prices, which, in the case of feed-in tariffs for PV-generated electricity, take a rather peculiar form. Indeed, FITs **create, frame and maintain a "forced" and regulated demand** and the conditions that sustain it (2).

On the other side of the transaction, FIT schemes provide potential photovoltaic electricity producers and sellers with a robust equipment that enable them to turn photovoltaics into an opportunity without putting much constraint on them (since FITs, at least in their basic form, are mainly concerned with the actual exchange of photovoltaic electricity, and not the way photovoltaic electricity was obtained in the first place). By **guaranteeing the conditions for the emergence and constitution of a diverse and potentially proliferating supply** of photovoltaic electricity (3), FIT schemes then carry the potential for multiple forms of re-entanglement of photovoltaic electricity and systems. Feed-in tariffs for PV-generated electricity are thus supposed to frame and stabilise photovoltaic electricity as an economic good *and* to trigger changes in the properties of photovoltaic electricity and technologies.

[59] The sketch feed-in tariffs for PV-generated electricity that I present in the next few pages builds on the French example. Its purpose is to provide an overview of the elements that come into play in the functioning of FIT schemes, and to outline the specificities of these market agencements. It remains very schematic and does not provide a thorough picture of French FITs and of their evolutions. These will be addressed in the next chapters, especially chapter 4.

2.1.1.1. Disentangling PV-generated electricity

The first framing that FIT schemes organise is **the disentanglement of photovoltaic electricity**. Feed-in tariffs for PV-generated electricity indeed aim to encourage the installation of photovoltaic systems by organising and facilitating the trading of the electricity they produce on large-scale electricity markets. To do so, they perform a qualification of photovoltaic electricity that makes it compatible with the functioning of electricity grids and markets, and commensurable with electricity generated from other sources. This implies a partial disentanglement of photovoltaic electricity from its source and from the modules that produce it. At the outcome of the operations that perform this disentanglement, photovoltaic electricity can theoretically be abstracted as a flow tradable on the grid as any others flow of electricity, with a specific but well-defined production profile (i.e. photovoltaic electricity is only generated when the sun shines) that can be managed by grid operators once they are equipped to do so. Electricity generated "using the Sun's radiative energy" is thus translated into a good that can circulate through the grid and be bought and sold as any other type of electricity.

This requires, first, the organisation of the connection of photovoltaic installations to the grid. Photovoltaic systems have to be stabilised as reliable providers of electricity. This operation is not framed by FIT schemes only (though it is largely regulated through administrative orders), but, since by definition feed-in tarrifs schemes imply the injection of photovoltaic electricity into the grid, their instauration triggers standardisation and normalisation processes (Interviews 10, 19). The composition of the balance of system had to be relatively stabilised[60] and, following the adoption of feed-in tariffs, norms and standards have been developed by photovoltaic installations suppliers to ensure the safety of photovoltaic systems as electric installations (Interviews 10, 19; norm NF-15-712-1). In parallel, grid operators have stabilised procedures for grid connection, which involve a classification of installations, administrative and registrations procedures, as well as the organisation of physical grid connection.

Second, FIT schemes directly qualify and stabilise photovoltaic electricity by defining the structure and content of purchase agreements. Since these agreements set the terms of the transaction, they list the characteristics of photovoltaic electricity to be taken into account, thereby enacting the disentanglement of photovoltaic electricity and its qualification as a tradable good (cf. Annex 2 for an example of purchase agreement).

By setting a price per kWh, they set a relevant metric. Such a formulation of price not only makes photovoltaic electricity commensurable with other forms of electricity (the price of which is, ultimately, expressed in the same unit); it also enables comparisons and references to several indicators used in energy economics, such as the LCOE or grid parity. In material terms, this framing is made performed thanks to electricity meters that record the quantity of electricity dispatched to the grid by a specific photovoltaic installations. This framing of photovoltaic electricity includes it in the same space of calculation as conventional sources of electricity, simultaneously making it comparable

[60] Power inverters in particular are crucial. Inverters are responsible for the conversion of the Direct Current generated by photovoltaic modules into Alternative Current. They also constitute the system's intelligence, as they have evolved to register and provide information on the amount of electricity being generated, and to react in case of problems.

and outlining its differences. It is also useful to assess the level and cost-efficiency of feed-in tariffs themselves, as it provides metrics for benchmarking.

The last qualification of photovoltaic electricity that purchase agreements (hence FIT schemes) perform is the standardisation of a definition of photovoltaic installations. They do so by listing the characteristics of photovoltaic installations that are to be taken into account in the transaction. In the French 2010 version, these include: total installed peak power, delivery tension, location (continental France or overseas territories), type of installation (e.g. ground-mounted, residential, installed on another type of building), and degree of building integration (MEEDDM 2010a, 2010e, 2010f). Photovoltaic installations are thus reduced to a few standardised qualities. This operation largely frames photovoltaic systems out of the transaction: only their size and their location are considered relevant.[61] In so doing, FIT schemes turn photovoltaic installations into silent intermediaries between the sun and the grid, or at least attempt to do so. These intermediaries can be classified according to a set of determined characteristics, but are not considered further. Or, rather, they were not in the initial version of the French FIT scheme, but the pacification and "intermediation" of photovoltaic installations turned out to be problematic, especially for those that were "building-integrated". It is not that there is something about photovoltaic systems that intrinsically resists pacification, but that FIT schemes have tended to stimulate the proliferation of their multiple and diverse re-entanglements.

2.1.1.2. Creating and maintaining a legally-bound demand for PV-generated electricity

The second framing that FIT schemes operate is **the creation and maintenance of a legally bound demand** for photovoltaic electricity. As a result of this framing, transactions involving photovoltaic electricity are in large part pre-negotiated, and purchasers have very little leeway on their terms.

FIT schemes determine a set of buyers who are bound by law to accept the purchase of photovoltaic electricity if a seller asks them to. Electricity retailers[62] are bound to connect photovoltaic installations to the grid and to purchase the electricity they produced if they are requested to do so; without this obligation, the vast majority of exchange of photovoltaic electricity would not take place. In France, the *Loi du 10 février 2000 relative au service public de l'électricité* reads as such:

> "Sous réserve de la nécessité de préserver le bon fonctionnement des réseaux, Electricité de France et, dans le cadre de leur objet légal et dès lors que les installations de production sont raccordées aux réseaux publics de distribution qu'ils exploitent, les distributeurs non nationalisés mentionnés à l'article 23 de la loi n° 46-628 du8 avril 1946

[61] In fact, even when only those two criteria are considered, the framing of photovoltaic installations can prove complicated. In particular, the existence of a high premium for building-integrated photovoltaics (BIPV) in France turned the definition of building integration into a crucial issue, which yet remains unsolved. Perhaps because building integration implies that photovoltaic systems are entangled to the buildings they are installed on (which are all different), the disentanglement of "BIPV" as a standardised good seems impossible to achieve.

[62] This obligation mainly concerns EDF, but in some areas it also involves local utilities that are responsible for the operation of local grids.

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précitée *sont tenus de conclure, si les producteurs intéressés en font la demande, un contrat pour l'achat de l'électricité produite* sur le territoire national par [...] *[les] installations de production d'électricité qui utilisent des énergies renouvelables* [...]. Un décret en Conseil d'État fixe les limites de puissance installée des installations de production qui peuvent bénéficier de l'obligation d'achat. Ces limites, qui ne peuvent excéder 12 mégawatt, sont fixées pour chaque catégorie d'installation pouvant bénéficier de l'obligation d'achat sur un site de production. [...]

Un décret précise les obligations qui s'imposent aux producteurs bénéficiant de l'obligation d'achat, ainsi que les conditions dans lesquelles les ministres chargés de l'économie et de l'énergie arrêtent, après avis de la Commission de régulation de l'énergie, les conditions d'achat de l'électricité ainsi produite. [...]

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Les surcoûts éventuels des installations de production d'électricité exploitées par Electricité de France ou par les distributeurs non nationalisés précités entrant dans le champ d'application du présent article font l'objet d'une *compensation* dans les conditions prévues au I de l'article 5. [...]

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Les contrats conclu en application du présent article par Electricité de France et les distributeurs non nationalisés mentionnés à l'article 23 de la loi n° 46-628 du 8 avril 1946 précitée *prévoient des conditions d'achat prenant en compte les coûts d'investissement et d'exploitation évités par ces acheteurs*, auxquels peut s'ajouter *une prime prenant en compte la contribution de la production livrée ou des filières à la réalisation des objectifs* définis au deuxième alinéa de l'article 1er de la présente loi. *Le niveau de cette prime ne peut conduire à ce que la rémunération des capitaux immobilisés dans les installations bénéficiant de ces conditions d'achat excède une **rémunération normale des capitaux,** compte tenus des risques inhérents à ces activités et de la garantie dont bénéficient ces installations d'écouler l'intégralité de leur production à un tarif déterminé*. Les conditions d'achat font l'objet d'une *révision périodique afin de tenir compte de l'évolution des coûts évités* et des charges mentionnées au I de l'article 5." (Loi n° 2000-108, article 10, emphasis added).[63]

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[63] Translating legal texts is challenging, which is why I chose to include the original version in the main text, but here is an attempt: "Provided that the good functioning of grids is maintained, *Electricité de France* [EDF] and, within the limits of their legal object and as soon as generation installations are connected to the public dispatch grids that they exploit, non-nationalised electricity retailers […] *are bound to conclude, if concerned producers ask for it, an agreement for the purchase of the electricity generated on the national territory by […] Electricity generation installations using renewable energy* […] A *décret en Conseil d'Etat* limits the installed capacity of the electricity generation installation that can benefit from purchase obligations. These limits, hat cannot exceed 12 megawatts, are determined for each category of installations allowed to benefits from purchase obligations on a production site. […]
A decree [*décret*] specifies the obligation that befall producers benefitting from purchase obligations, as well as the conditions under which *ministers in charge of economy and energy determine the conditions for the purchase of the electricity so generated*, after notice from the *Commission de regulation de l'électricité*. […]
Potential additional costs resulting from the electricity generation installations exploited by *Electricité de France* […] *are compensated* as provided for in article 5, I. […]
The agreements concluded in enforcement of the present article by *Electricité de France* […] provide purchase conditions that take into account the investment and exploitation costs avoided by said purchasers, *to which may be added a premium taking into account the contribution of delivered production or sectors to the achievement of the objectives defined in article 1, alinea 2 of the present text* [i.e. objectives of the "electricity public service", including environmental protection objectives]. *The level of this premium cannot lead the remuneration of the capital invested in the installations benefitting from these purchase conditions to exceed a normal*

State regulations taken within the framework of this bill thus provide for most of the decisions of buyers as far as the purchase of photovoltaic electricity is concerned; at the very least, they frame them in a very constraining way. Regulatory documents frame the purchase of photovoltaic electricity, but they also arrange many administrative and technical details pertaining to grid connection, including the allocation of the costs of connection and grid management and maintenance. They also determine the level of the compensation of the costs incurred to EDF and others by the purchase obligation, and the criteria for calculating it.

Last, the formulation of prices also itself is a matter of State regulation. The formulas for FIT rates calculation are determined by State agents and policymakers in the relevant ministry. They are then assessed by an independent administrative authority, the Commission de Régulation de l'Electricité (CRE), which provides a notice on regulatory texts regarding FIT schemes.[64] The CRE particularly assesses the cost-effectiveness and fairness of FIT schemes to ensure that they deserve to fall in the scope of "the electricity public service" (Interview 22). An important constraint regarding the level of feed-in rates is that they must not lead to a remuneration of photovoltaic electricity that "exceeds a normal remuneration of capital taking into account the risks inherent to these activities and the guarantee to sell their whole production at a determined tariff from which these installations benefit" (Loi n°2000-108, article 10). The formulation and assessment of FIT rates partly rely on information on market evolution provided by EDF and other grid operators: number of new purchase agreements signed, number and size of new installations...

In short, FIT schemes effectively organise the transfer to the State of the calculative capacities of photovoltaic electricity purchasers. These are, in a way, deprived of economic agency: all of "their" decisions relative to the transaction are made and regulated through State regulation. They can try to influence policy makers, but in the end have no option but to comply. In the event that they have difficulties doing so, the matter is not negotiated between purchaser and seller (as it would be in a market transaction), but brought to court of justice. This has been a source of problems for ERDF, in charge of connected photovoltaic installations to the grid within a fixed delay: owing to difficulties in facing the number of grid-connection requests due to the surge in photovoltaic projects in the late 2000s, they have not always been able to respect legal delays, which resulted in trials (Interview 25).

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remuneration of capital, taking into account the risk inherent to these activities and the guarantee to sell the totality of their production at a determined tariff from which such installations benefit. Purchase conditions are subjected to periodic revisions so as to take into account the evolution of avoided costs and of expenses mentioned in article 5, I."

[64] The *Commission de Régulation de l'Energie* (CRE) is an independent administrative authority created in 2000 and in charge of ensuring the good functioning of energy markets, including the markets for gas and electricity, and to arbitrate disputes relevant to these markets.

2.1.1.3. Constituting a protected and diverse supply of PV-generated electricity

On the other hand, this transfer of calculative capacities enables potential photovoltaic electricity suppliers to fully deploy their inventiveness in constituting those pre-framed deals into opportunities. FIT schemes thus generate a strong asymmetry between purchasers whose hands are virtually tied, and suppliers who are provided with a particularly comfortable space for economic action. This is the third framing that FIT schemes organise: they **enable and encourage the constitution of a protected and diverse supply** of photovoltaic electricity.

The point of FIT schemes is indeed to trigger specific economic actions, namely the installation of photovoltaic systems for the generation and sale of photovoltaic electricity. On the demand side, FIT schemes capture the economic agency of purchasers and turn them into passive intermediaries that will comply with these ends. On the supply side, on the contrary, FIT schemes aim to equip agencies in a way that divert their behaviours towards these ends without much concern for the means employed.

To spark such behaviours, FIT schemes pre-frame transactions that are *bound* to be interesting for potential suppliers of photovoltaic electricity. They spell out an opportunity backed by the State, and thus provide extremely strong guarantees that ensure that favourable conditions will be maintained. The securing of a reliable and favourable investment framework is a condition of the effectiveness of feed-in tariffs: feed-in tariff schemes that do not guarantee sufficient returns on investment to ensure profitability yield no results. The first French FIT for photovoltaic (2002-2006), set at a level that could hardly compensate for investments, thus had virtually no effect on installed photovoltaic capacity.

FIT schemes usually do not specify who can benefit from these favourable conditions, which would be unconstitutional. In principle, the opportunity is thus open to anyone.[65] The calculative equipment provided by FIT schemes is made largely available and agencies on the supply side are not really framed. Those targeted by FIT schemes, that is, potential photovoltaic electricity suppliers (or, in other words, anyone with access to photovoltaic resources, i.e. to well-exposed surfaces), are thus left with great freedom as to how to actually seize the opportunity and constitute themselves as owners of a photovoltaic installation. What matters is the transaction, that is the existence of photovoltaic electricity that is compatible with the requirements of the purchase agreement – i.e. that can be traded on the electricity grid. At first, in France, the production process itself was to a large extent left out of the scope of FIT regulations.

This had to do with the framing of photovoltaic electricity as a good, and is reinforced by the modular character of photovoltaic. As mentioned above, FIT schemes largely frame photovoltaic systems as passive intermediaries or black boxes that generate electricity from sunlight in a predictable manner. Photovoltaic systems are considered as stable, passive entities, when FITs in fact *also* activate them as mediators.

[65] The law has to be the same to everyone. Given the legal impossibility to discriminate between categories of photovoltaic producers, restrictions on the kinds of photovoltaic installations eligible have targeted technical characteristics, e.g. installations size, even when they were primarily meant to exclude specific types of photovoltaic producers (Interview 15).

Photovoltaic modules can be considered as pacified, predictable entities because their function is stabilised; they are defined by their ability to reliably generate electricity from light. Precisely because of their stability in performing this specific, well-defined function, they can be arranged in multiple ways within a FIT-framed photovoltaic economy: photovoltaic systems can take very diverse forms and still perform the same function, that is be ultimately qualified as installations generating a measurable amount of electricity from a fatal resource. In other words, as far as the transaction of photovoltaic electricity is concerned, the actual arrangements through which the traded good has been produced can be bracketed out: they do not alter the qualities of the good.[66] The great polyvalence of feed-in tariffs for PV-generated electricity, that is to say their capacity to support a very large range of projects, stems in large part from this specificity of photovoltaics. The fact that photovoltaic modules encapsulate a stabilised function creates a channel for inventiveness: photovoltaic systems can be combined in multiple forms of varying sizes and scales while remaining within the frame of FIT market *agencements*.

By encouraging the constitution of a supply of photovoltaic electricity, FIT schemes thus create a demand for photovoltaic electricity generation systems; but, since such systems can take very diverse forms, this demand is hardly framed.[67] As a result, all the work required ahead of the arrangement of the transaction of photovoltaic electricity is left unregulated (or at least loosely regulated). FIT schemes focus on the endpoint of photovoltaic projects, namely the owner of the photovoltaic installation. She is the one actually seizing the opportunity, but to do so she relies on the enrolment and cooperation of (human and non-human) partners: as Doganova has shown, the construction of an economic opportunity is a process of collective exploration (Doganova, 2009). Thus, by equipping an agent and sparking her into action, FIT schemes set into motion long chains of mediators,[68] triggering market activities that they do not regulate entirely.

FIT schemes then organise only one part of the activities that take place on photovoltaic markets, leaving the rest to deploy and arrange in a wide variety of forms. Still, the opportunity framed by feed-in tariffs for PV-generated electricity constitutes an outlet for these activities, thereby directing them towards the accomplishment of transactions articulated by FIT schemes. It does not, however, constrain them: agents are free to organise their action (and to modify photovoltaic systems) so as to maximise the opportunity, as long as this opportunity remains within the perimeter defined by the

[66] FIT schemes can however be modified so that the characteristics of the installation generating the electricity come to alter the nature of the good exchanged; the electricity produced can for instance be labelled (in the purchase agreement) as coming from a building-integrated installation, which – in France – endows it with a higher exchange value than electricity labelled as originating from a ground-mounted photovoltaic plant. This constitutes a strategy for reinforcing the structuring quality of FIT schemes, hence their predictability, and can thereby make them more acceptable, but is not a condition of their functioning.

[67] Here again, this only holds true for a "basic" FIT scheme, that is one that does not include conditions regarding the qualities of photovoltaic systems, which was the case in France before 2010 (except for BIPV).

[68] Including photovoltaic modules producers, project developers, installers, etc… Chapter 5 provides an example of the amount of work and partners required to carry out a photovoltaic project.

law, that is does not exceed a "normal remuneration of capital".[69] Multiple re-entanglements are made possible and, to an extent, encouraged. This applies to the arrangement of photovoltaic installations and of all the activities they imply, but also to the characteristics of photovoltaic modules.

Indeed, triggering learning-induced cost reduction and stimulating innovation is an explicit objective of FIT schemes. Within a FIT regime, reducing the price of photovoltaic systems and modules is a way to enhance the profitability of trading photovoltaic electricity, since it creates a discrepancy between installation costs and the sale prices that investors can benefit from. It thus encourages photovoltaic project developers to look for the cheapest options available. On the other, by guaranteeing an outlet for photovoltaic modules, it encourages the deployment of module production capacities. FIT schemes thus trigger learning, innovation, and industrial processes whose developments cannot be predicted – and that can have consequences as large as the deployment of a massive supply of low-costs photovoltaic cells manufactured by State-subsidised Chinese firms. These processes can lead to transformations in the properties of photovoltaic modules and systems, because they involve attempts at modifying them so as to make them more profitable within the market *agencements* that FIT schemes organise.

FIT schemes thus bear the seeds for unexpected effects and overflows. The unpredictability of their consequences is, to an extent, inherent to the logic of these instruments: they work by triggering action and action, by definition, implies series of translations and mediation. In that, FIT schemes have an experimental character;[70] they set in motion a collective process of exploration and learning, the outcomes of which cannot be laid out in advance, but have to be documented and tracked in order to maintain the market *agencements* that triggered them.

2.1.2. Feed-in tariffs as incentives: the attachments that drive market activities

FIT schemes are market *agencements* that constrain the better to let go. They frame the trade of photovoltaic electricity in a rather strict way (even if photovoltaic producers can

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[69] It should be noted that this is not something that market actors themselves can control, since it depends on the differential between the costs of photovoltaic installation and the level of feed-in tariffs. However, in the event that "normal remuneration" is exceeded, the State is legitimate to reconsider the feed-in scheme.

[70] The term "experimental" has a long career, especially in STS research (cf. glossary). Here, I use it in the perspective that Marres has qualified as an "ontological account of public experiments" (Marres, 2012), which is characterised by the notion that public experiments introduce new entities in social and political life and thereby entail "reconfigurations of social-material relations" (Marres, 2012, p. 87). This perspective stresses the active role of objects and social actors in public experiments, understood as "attempt[s] to secure the necessary involvement of social actors in the process of the domestication of scientific, technological natural and-so-on entities in society" (Marres, 2012, p. 87). Referring to the experimental character of feed-in tariffs for PV-generated electricity thus points to the empirical approach to their assessment and adjustment (i.e. implying recording, monitoring, reporting and demonstration of their effects) on the one hand, and to the fact that they aim to *engage* social, political and economic actors in the "domestication", diffusion and exploration of grid-connected photovoltaics.

still choose not to sell according to this *agencement*). At the same time and, in fact, *because* of that, they provide the conditions for the emergence and deployment of diverse and unpredictable courses of action. One could almost say, embracing the paradoxical character of the expression, that they are intended to provoke unintended consequences. But they can only do so if they are well adjusted, well calibrated, and sufficiently predictable to provide a reliable frame of action to potential buyers and sellers.

As I have in the previous section, the notion of *agencement* conveys this tension and interdependence between structuring and letting go. The interplay of disentanglement and re-entanglement, framing and overflowing suggests that it is in fact at the heart of market activity as approached by ANT theorists. The description of FIT schemes echoes that of the marketing processes that Franck Cochoy has labelled as "***captation"***, with the difference that Cochoy focuses on the *captation* of buyers and customers, whereas FIT schemes aim to influence potential producers and traders (Cochoy, 2007). This notion was coined to describe the strategies and devices deployed to influence, divert, and manipulate fleeting and fluid collectives such as "citizens, users, electors, buyers, consumers, clients" (Cochoy, 2007, p. 204). By *captation,* Cochoy designates "the ensemble of operations which try to exert a hold over, or attract to oneself, or retain those one has attracted" (Cochoy, 2007, p. 204).

What is particularly interesting about the term *captation* is that it tries to **capture the ambivalence of the process of seducing, deviating, and exerting a hold over** users, clients, consumers, etc. *Captation*, Cochoy writes,

> "is a matter of having a hold over something that one does not, or rather not yet, completely control. In captation, one thus meets a figure which applies to hunting, to war, to love, in politics or concerning the market: the care and the effort put into establishing a bond without any guarantee of succeeding. […] '*Capter'*, to lure oneself, is thus to paradoxically accept the possibility of strangeness, of departure or indifference, and even to allow one's target freedom […]" (Cochoy, 2007, p. 205).

Or, as he says in fewer words:

> "Captation supposes an opening, mastery implies dispossession" (Cochoy, 2007, p. 205).

The best way to grasp this peculiar dynamic, I think, is to rely on the notion of ***attachment***. The concept of *attachment* was initially developed to prolong that of mediation. It took shape in the crossing of Hennion and Teil's accounts of the experience of *amateurs* and of Gomart's work on methadone (Gomart & Hennion, 1999). The challenge with such case studies was to render **processes of "active conditioning so that something might arrive"** (Gomart & Hennion 1999) that cannot be reduced to interactions of causal objects and intentional persons. It thus implies a redefinition of causality and a redistribution of agency, as it aims to provide a means to **move beyond the passive/active dichotomy**. The term *attachment* does not describe links of causation or intentions, but **networks of ties that "make/let happen" (qui "font faire")** and **set entities in motion**. As Hennion summarizes in his overview of the notion:

> "... les liens de nature très diverses dans lesquels nous sommes pris, qui nous tiennent et nous font tenir, appellent une redistribution de l'agence, déployée dans cet entrelacs où chaque lien fait quelque chose, mais où aucun ne suffit. Comme Bruno Latour le relevait, l'idée d'attachement implique aussitôt une remise en cause de la causalité, au profit d'interactions moins nettes : des poussées, des frottements, des entrainements réciproques. Plus de partage clair entre des choses déterminantes et des choses déterminées, on passe de l'oscillation binaire actif/passif à la continuité, moins tranchée,

mais autrement productive, d'une action distribuée, un 'faire faire' disséminé dans ces réseaux (Latour, 2000)." (Hennion, 2010, p. 180)[71]

Attachments thus make it possible to **redistribute agency along chains of mediations in which each link is set into motion and by moving sets others into motion**. But, because it rearticulates the dichotomy between passivity and activity, it also provides an **alternative manner to approach the tension between constraint/framing and letting go/overflowing**.
"L'attachement désigne à la fois ce qui émeut, ce qui met en mouvement, et l'impossibilité de définir ce faire faire par l'ancien couplage de la détermination et de la liberté." (Latour, 2000, p. 16-17)[72]

The notion thus precisely captures the complex articulation between mastery and dispossession, determination and liberty, as well as the amount of (active) work needed to achieve passivity.

"[N]ous visions l'articulation fine d'une attention et d'un contrôle minutieux – mais dans les choses mêmes, dans l'abandon – avec un abandon et un emportement – mais ce "lâcher prise" réembrayant aussitôt sur de l'évaluation, des récits d'expérience, la réappropriation d'une histoire…" (Hennion, 2010, p. 185)[73]

Viewed in this light, the ambivalence of FIT schemes is not a paradox, but rather what explains their functioning. The success of FIT schemes in fact hinges on their **capacity to articulate and balance the tension** between **framing, constraining, structuring, conditioning** on the one hand ("*faire* faire"), and **letting go, setting into motion, triggering action, overflowing** on the other ("faire *faire*").

More generally, Callon would suggest that the management of such tension is what is at stake in market *agencements*:

"La réussite de l'action collective déployée par les agencements marchands dépend donc du cadrage délicat qu'ils opèrent entre les forces qui poussent à l'intrication et à l'ouverture et celles qui poussent vers la désintrication et vers la fermeture." (Callon, 2013, p. 384)[74]

[71] "… the very diverse ties in which we are caught, that bind us and hold us together, call for a redistribution of agency, deployed in these interlacements in which each links does something, but none is enough. As Bruno Latour noted, the idea of attachment immediately implies a questioning of the notion of causality to the benefits of less clear interactions: pushes, frictions, mutual impulses. No clear separation between determining things and determined things, we shift from the binary oscillation active/passive to the less clear-cut but much more fertile continuum of distributed action, a 'let do' ['faire faire'] spread along networks." (author's translation)

[72] "The attachment designates at the same time what moves, what sets in motion, and the impossibility to define this "let do" ["faire faire"] through the old coupling of determinacy and freedom." (author's translation)

[73] "we aimed for the delicate articulation of meticulous control and attention – but within the very things, within abandon – with abandon and letting go – but this "losing grip" just as soon re-embarks on assessment, relations of experience, the re-appropriation of a story…" (author's translation)

[74] "The success of the collective action that market *agencements* deploy thus depends on the delicate framing that they operate between forces that carry towards entanglement and opening and those that carry towards disentanglement and closure." (author's translation)

For this to function, FIT schemes need to be able to trigger action: the constraint they put on purchasers is only a constraint if it manages to interest sellers. The purchase obligation and the price guarantee they set must be sufficient to create a protected space for investment in which novelty can then deploy. It does not take much for a FIT scheme to fall short of its goal, which is to direct action towards the trading of photovoltaic electricity. Calibration, then, is crucial. In a regulated market such as that organised by FIT schemes, public authorities are ultimately responsible for this calibration. It follows that those involved in transactions are not the only ones negotiating and adjusting market *agencements*, and that the ultimate arbiter does not directly take part in the exchange, and has a very specific status.

Through which processes is this calibration performed? How are the overflows and unintended consequences of FIT *agencements* managed and regulated? In short, how is the collective action triggered and framed by FIT schemes coordinated?

2.2. The politics of feed-in tariff calibration

To consider the issue of the calibration of feed-in tariffs, one has to look at the roles of politics and technologies in the operation of market *agencements*. From a more general perspective, it is an angle from which to approach the interactions between markets, politics and technologies at play in the emergence of photovoltaic.

The calibration of feed-in tariffs involves the **setting of their level** (i.e. of the feed-in rate) and the **design and performance of the formulas through which it is established and adjusted**. As outlined above, it is necessary to the functioning of feed-in tariffs: a well-calibrated tariff is supposed to both trigger and regulate the development of photovoltaic. Calibration is, however, not just a matter of market organisation. This stems from two of their distinguishing characteristics that I will explore in this section.

First, FIT-driven photovoltaic markets are, by definition, **regulated markets**. This means that, contrary to most market *agencements*,[75] the calibration of feed-in tariffs is not the outcome of a negotiation between those involved in the transaction, but that of political negotiations in which the State has the last word.

Second, these markets are **regulated but not stabilised**. Indeed, I have shown that FITs work by activating agencies and technologies whose reactions cannot be known in advance and depend in large part on the calibration of FITs. By investing agents and things with economic and political capacities, feed-in tariffs generate unintended consequences. These have to be documented and taken into account in the fine-tuning that is necessary to keep FITs working, which can constitute a major challenge. At play in the calibration of FITs, hence in the regulation of the development of photovoltaic, is

[75] At least in the general framework suggested by Callon, who stresses that "in a market *agencement*, the price results (as with any bilateral transaction) from the confrontation of a buyer and a seller" ["Dans un agencement marchand, le prix résulte (comme pour toute transaction bilatérale) de la confrontation entre un acheteur et un vendeur"] (Callon, 2013, p. 391, author's translation).

the management of the tension between the regularity and stability that and market actors need, and the unpredictability that their activity generates.

2.2.1. Regulating the development of photovoltaics

Studying a policy-driven, regulated market such as that for photovoltaic electricity entails a consideration of the relationships between politics and economics, or rather an exploration of the distinctions and relations between that which pertains to political processes and that which pertains to market activities. It then implies a reflection not only upon the specificities of market activities, but upon those of political activities as well.

That the functioning of markets cannot be understood independently from power relations, politics and institutions is an essential claim of economic sociology. An extensive body of work has studied dynamics of institutionalisation and change within markets and industries (e.g. Leblebici et al., 1991; Lounsbury et al., 2003; Navis & Glynn, 2010), the social embeddedness of markets (Granovetter, 1985), and the role of states, politics and institutions in structuring and maintaining markets (Fligstein, 1996). For proponents of embeddedness, “markets are products of a political process” (Breslau, 2013, p. 830).[76]

Though the ***performativity*** approach developed by Callon and others was clearly influenced by such analyses, it diverges from the embeddedness approach in particular in that it grants an active role to economics and economic models in the making and performance of markets (Callon, 2007; MacKenzie et al., 2007). Though it has been criticised for siding with the economists and downplaying the role of social and political processes in the economy (Miller, 2002), performativity in fact takes power and politics as seriously as it does economic theories. In fact, by stressing the crucial role of economic theories and experiments in the organization but also in the critique of markets, performativity introduces politics “into the heart of debates on the organization of economic activities” (Callon, 2010, p. 168). Market *agencements* indeed comprise of knowledge, theories, procedures, people, material objects, and power relations. For the performativity literature, economics (as a set of theories and models of the economy) is caught up in power struggles as much as it contributes to formatting them.

> “With the concept of performation, observable reality is considered as the temporary outcome of confrontation between different competing programs, including scientific ones. The historical dimension of processes is emphasized, as well as the fact that history

[76] New economic sociology and the study of “the social embeddedness of markets” developed in reaction to neoclassical accounts of the functioning of the economy, which failed to account for the role of social and political processes. As Breslau summarises, from the perspective of economic sociology, “the process of market formation cannot be said to proceed according to a logic of self-correcting progress. Markets are products of a political process. Of the elements that comprise markets – property rights, rules of exchange, unwritten norms, and a cultural context – all are potential objects of political contention, and their configuration at any moment is the product of previous rounds of struggle (Bourdieu, 2005: 193-216; Fligstein, 2001; Samuels, 2004). Interested actors, those selling of seeking whatever is transacted, try to embed their interests in the rules of the market, often by influencing regulatory authorities, or intervening in judicial proceedings.” (Breslau, 2013, p. 830).

> matters and that the economy and markets are temporary and fluctuating results of conflicts and the constantly changeable expression of power struggles. The history of these struggles is incorporated into markets, just as a living organism retains traces of its evolution." (Callon, 2007, p. 32).

Case studies following the performativity approach have well documented the roles of materialities and knowledge in the making and framing of various types of markets (e.g. Beunza et al., 2006; Holm, 2007; MacKenzie, 2003, 2009; Muniesa, 2005). The performativity approach has also informed case studies and reflections on the relationships between politicisation and economisation (Barry & Slater, 2002; Callon, 2007, 2010; Cochoy et al., 2010; Muniesa, 2010; Linhardt & Muniesa, 2011) as well as studies of the politics of specific market *agencements* and of their relations to state regulation (e.g. Mitchell, 2011; Holm & Nielsen, 2007; Debourdeau, 2011b; Breslau, 2013).

In the case of feed-in tariffs for PV-generated electricity, the interweaving of market *agencements*, economics and politics is explicit. Since they are designed to frame market transactions, FITs cannot be accounted for as political instruments only; but neither can they be fully understood if considered as mere market *agencements*. One key argument of this dissertation is that FIT schemes only work as long as their political and market dimensions are articulated – they cannot work if disconnected from politics, and they cannot work if not linked to market mechanisms and economic logics.

First, feed-in tariffs for PV-generated electricity aim to create markets from scratch by generating a supported and regulated demand. As shown above, they organise the transfer of calculative capacities from purchasers to the State. In that, they are similar to the capacity markets analysed by Breslau as "market-like entities" (Breslau, 2013). Capacity markets provide a way to ensure the reliability of electrical power systems by guaranteeing that sufficient generating capacities is available to supply peak loads. They are, however, not exactly "markets", as the transactions that take place in them are politically framed (perhaps even more strictly than with FITs).[77] Purchasers have no say in the framing of the product or the calculation of its price: the capacity market "is an institution organized for commerce in a good that has no intrinsic value to buyers; they purchase it only because they are required to do so" (Breslau, 2013, p. 833). Breslau shows that, in spite of their thoroughly regulated character, capacity markets are in fact designed so as to approximate the transactions that abstract economic models would predict in a theoretical market. Precisely because their success relies on economic theories and economic data collection, such regulated market *agencements* are distinct from political or administrative planning, and can be considered as a hybrid category of their own. They indeed "try to institute a market mechanism to do the reliability assurance work formerly charged to an administrative planning process" (Breslau, 2013, p. 834).

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[77] A crucial difference between FITs and capacity markets is that the former, contrary to the latter, are meant to be transitory. FITs frame transactions involving electricity from renewable energy sources as long as these would not happen otherwise; but they are also meant to trigger cost reductions and learning processes that are expected to make electricity from renewable energy sources competitive by themselves. A working FIT scheme should thus eventually lead to its own disappearance.

In a similar fashion, with feed-in tariffs, policies institute the framings necessary for specific market transactions to take place. Policy-makers are ultimately responsible for the regulation of these transactions and the calibration of market *agencements*. In France, the general framework for FITs is established by law. Modalities for specific sources of renewable electricity, such as formulas for establishing FITs rates or conditions of applicability, are detailed in *décrets* published by the relevant ministry (i.e. the ministry in charge of energy and/or the economy). Each of these *décrets* is assessed by the CRE, which provides non-binding expertise on issues pertaining to energy markets. Though the process can (and often does) involve consultations with various stakeholders, the decision lies in the hands of administrative and political officials.

However political the process may be, the objective of feed-in tariffs remains to frame and sustain viable market *agencements*. Their design and calibration thus relies on economic models and market data as much as on political and institutional resources. As the lengthy academic discussions on the best design of feed-in tariffs and their compatibility with deregulated energy markets studied in chapter 3 suggest, they aim to institute markets that conform theoretical models, especially insofar as one of the justification for renewable energy support is to "level the playing field" and to correct some failures of current energy markets. It is the legal constraint that makes FITs operational (because purchasers are forced into transactions), but they cannot function unless they make economic sense (here, the adjective "economic" equally refers to economic practice and theory).[78]

Still, given the hybrid character of FITs, making economic sense is not the only requirement that they have to meet. In her studies of what she calls "the concretisation of photovoltaics" (Debourdeau, 2009, 2011a, 2011b), Debourdeau stresses the fact that in the case of photovoltaics, marketisation and politicisation go hand in hand:

> "Le politique, *via* différents instruments d'action publique, s'avère une instance primordiale de cadrage de la *marketization* du photovoltaïque : son intervention est nécessaire (mais non suffisante) à la compensation transitoire de la non-compétitivité de l'électricité d'origine solaire. L'engagement des pouvoirs publics dans les « politiques énergétiques du futur » (Laird, 2004) est par conséquent délibéré et mesuré à l'aune de modélisations économiques. L'appariement économie/politique constitue une condition *sine qua non* du développement du photovoltaïque par sa *marketization*" (Debourdeau, 2011a, p. 53)[79]

[78] Making economic sense is of course necessary for FITs to function as market devices because they need to frame economically viable transaction to attract interest; but, in some instances, it is also necessary for them to be politically acceptable: for instance, the European Commission used to disapprove of feed-in tariffs on the ground that they did not conform the theoretical requirements of market integration, which was a prominent political objective of the Commission (cf. Chapter 3 below). Thus, making economic sense is not necessarily distinct from making political sense.

[79] "Through various public action instruments, politics turn out to be a primary instance for the framing of the *marketization* of photovoltaic: their intervention is necessary (but not sufficient) to the transitory compensation of the lack of competitiveness of solar electricity. The involvement of public authorities in 'future energy policies' (Laird, 2004) is thus deliberate and determined according to economic models. The economic/politics coupling is an imperative condition for the development of photovoltaic through *marketization*." (author's translation)

As Debourdeau pointed out (2011a, 2011b), resorting to FITs to develop renewable energies and contribute to the achievement of climate policy objectives implies a specific political stance: the choice of market mechanisms as ways to transform energy policies (Debourdeau, 2011b, p.114). FIT schemes imply the choice of "dealing with energy and climate issue through policies of creation and mass-development of renewable energy markets" (Debourdeau, 2011b, p. 111, author's translation).[80] It follows that the arrangement of renewable electricity markets (including photovoltaic markets) is explicitly meant to alter the balance of powers on electricity markets by novel objects and players with reinforced economic agency. As such, the implementation of FIT schemes carries a definition of the common good. Indeed, in France, the promotion of renewable electricity falls under the scope of the electricity public service, which implies that it can be funded by the collective of electricity users through a levy, the CSPE (Loi n° 2000-108).

The definition of FIT schemes as contributing to the achievement of political objectives is flexible, in that they can be considered to do so in several – and not necessarily compatible – ways (climate change mitigation, environmental protection, innovation, industrial development, job creation…). However, it constitutes an additional requirement that FIT schemes have to conform with to be maintained. FITs do not only have to make economic sense; they must make political sense as well – it being understood that neither "economic sense" nor "political sense" are immutable. This double constraint is translated by the legal requirement that FITs do not lead to excessive remuneration of capitals, and it is crucial to understand the functioning and evolution of FIT schemes and the issues posed by their calibration.

2.2.2. Managing overflowing markets and political issues

Debourdeau stresses another aspect of the "politicisation" of photovoltaic electricity through feed-in tariffs. The marketisation of photovoltaic electricity through FIT schemes is political in that it was developed as a solution to address specific political issues, but also because it eventually sparked problems and contestation (Debourdeau, 2011b). To draw a parallel with the sociology of public instruments, the politics of FIT schemes lie in their effects as much as in their design (Lascoumes & Le Galès, 2005, 2007).

Three characteristics making FIT design a political activity have been outlined in the previous pages. First, FITs are instruments that translate political objectives and, in that, rely on a definition of the common good. As political instruments, they are administered, calibrated and regulated by policy makers and state officials: decisions regarding FIT schemes are ultimately political decisions in which the State has the last word. Last, because FIT schemes frame market transactions and equip economic agencies, they organise calculative asymmetries; as a result, their design influences the balance of power in photovoltaic transactions and to an extent determines who benefits from the emergence of photovoltaic markets.

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[80] "Mais avec la dissémination des tarifs d'achat garantis se diffuse également le mode de problématisation subsumé sus l'instrument, celui de la prise en charge des enjeux énergétiques et climatiques par des politiques de création et de massification des marchés des énergies renouvelables."

There is another dimension to the politics of feed-in tariffs. It stems from the fact that FIT schemes are designed to produce effects that are not entirely predictable. As market *agencements*, FITs organise and trigger market activities, which are supposed to "self-regulate" to an extent – especially since FIT schemes are meant to be transitory measures to accelerate the proliferation of specific market transactions that are eventually supposed to take place unsupported. However, FIT schemes do more than just enable market transactions insofar as they rely on (economic, technological, and arguably social and political) innovation. They activate new forms of agencies, generate public issues, and spark novel kinds of mobilisation, which in turn feed back on their design. FIT schemes thus trigger processes that they cannot fully control and, crucially, that is part of their aim: they are meant to trigger the emergence of novelty.

How, then, to give account of the effects of FITs? What does it mean to say that these are political? To what extent can the political dimension of FIT schemes be considered as included in the functioning of FIT-driven photovoltaic markets?

2.2.2.1. How markets spawn political issues

STS research on economic activity has shown the production of unintended effects, or overflowing, to be a consequence of the functioning of markets (Callon, 1998, 2007, 2009). Externalities, overflowing, and more generally the issue of the shifting boundary between what is inside the market and what is outside of it, have been a core concern of STS research on the sociology of markets (Callon, 1998).

A crucial contribution of such approaches has been to show that "the economy" and "markets" are not pre-existing, distinct spheres of activity with well-defined and stable boundaries. Instead, they are constituted by operations of framing that define certain things and agent as economic and others as non-economic. From such a perspective, that which is "outside" markets is not intrinsically non economic, and cannot be considered as a "context"; rather, it has been framed-out, that is to say excluded from the realm of market activities. But such framings are fragile achievements: precisely because they produce exclusion, they are always contestable. In addition, framings are always imperfect and produce overflows that sometimes lead to reconfigurations (Callon, 1998). That which was deemed irrelevant to economic activity at some point may later need to be considered. In other words, it may turn (or rather be turned) into a matter of concern (Callon, 2007). Market framings thus "spawn matters of concern" (Callon, 2007, 2009) because they produce exclusion and because they inevitably trigger overflows:

> "Market framing constitutes powerful mechanisms for exclusion, for to frame means to select, to sever links and finally to make some trajectories (at least temporarily) irreversible. Certain worlds, with their goods, agents and attachments, are chosen above others which are consequently threatened with extinction. This is the first source of matters of concern. Since framings are never completely successful, overflowings occur, which constitute a second possible source." (Callon, 2007, p. 140)

The emergence of such matters of concern and overflows calls for re-adjustments of market framings. Hence, the boundaries of markets, that is to say the list of entities and issues whose management is delegated to market institutions and operations, are fluctuating and always potentially subject to reconfigurations. As Barry and Slater wrote:

> "An 'externality', in Callon's account, is very different from a social context: formatting market institutions in ways that entail specific modes of calculation involves framing a range of features as relevant, and by definition excluding others (these are no longer economic factors, but cultural or ethical or political). The latter are not a context within which market behaviour is conducted but are themselves a result of the very same operation through which a market is (provisionally) defined in the first place. Externality and framing describe the way in which 'insides' and 'outsides' emerge, and change, in relation to highly political and material processes. The very patterning of elements within the market that entail 'calculativeness' appear there because of (disputable and unstable) acts of separation and division, not because 'values' are imported from a pre-given outside to be applied to an equally given inside." (Barry & Slater, 2002, p. 182-3).

As a result, in this perspective, "the distribution between the political and the economic is not anterior to the market; it is the outcome of the functioning of markets, of which it is a by-product" (Callon, 2009, p. 542). Further than that, this distribution is shifting, since it produces overflows and matters of concerns that challenge it and put it at test.

> "This (re)distribution is constantly tested, criticized, debated, reconstructed and consequently subjected to endless redefinition and reconfiguration. This means that its stability, when it exists, can be obtained only by means of a set of investments that are at once cognitive, material and institutional, without which its maintenance is not guaranteed." (Callon, 2010, p. 165)

The maintenance of markets involves the maintenance of the distribution between that which will be addressed through political processes and institutions and that which will be left to market transactions and regulation, "knowing that it is always likely to be revised and redefined" (Callon, 2010, p. 164). It follows that any process of marketisation is also, simultaneously, a process of politicisation (Callon, 2010, p. 164), and it is so in a least two respects: because the distribution between "politics", understood as the codified management of public affairs (Barry, 2002) and "economics" is an outcome of marketisation, and because market framings generate matters of concern that can have political consequences.

Overflowings, their transformation into matters of concerns and the reconfiguration of markets and/or politics that it may entail are effects of the functioning of markets, and, by definition, they are unintended. Their emergence cannot be predicted with absolute certainty, and the re-adjustments of market framings that they may induce cannot be planned ahead. However, it needs to be documented and accounted for.

> "No one, not even the best specialists, can be entirely sure in advance of the organizational forms and material *agencements* needed to establish a market's functioning. Concrete markets can be described and analysed *in vivo* only, which implies the establishment of devices for measuring, monitoring and watching them, to constantly keep an eye on the problems they pose and the way in which they react to certain interventions or adjustments." (Callon, 2009, p. 536)

The establishment of a market can thus be described as an experimental process that can occur both *in vitro* (economic models, research, design of instruments and study of market mechanisms…) and *in vivo* (economic activities, development of new business models, institutions…) (Muniesa & Callon, 2007). Markets can then be conceived of as "reflexively designed devices and as on-going scale-one experiments" (Callon, 2009, p. 536).

This characteristic is especially striking in new markets that have been explicitly politically engineered, such as carbon markets (Callon, 2009) or renewable energy markets. Callon points out that the establishment of carbon markets (at least in the European Union) is explicitly structured as a process of collective experimentation driven by EU institutions and involving material, procedural and textual elements as well as a large range of actors and competencies, from economists to economic agents to NGOs (Callon, 2009, p. 538; Braun, 2009). I would argue that the development of FIT-driven photovoltaic markets follows a similar process.[81] Both aim at the creation of new markets virtually from scratch, thus at the organisation of market *agencements* that deal with novel entities and can foster innovation. And both organise, in fact in a rather similar manner, the collection of data, feedback and assessments on the effects of these *agencements*.

Following this line of thought, the deployment of photovoltaic markets in the EU, like that of carbon markets, can be described as a process of collective experimentation driven by policy objectives, and through which the distribution between politics, techno-science and economics in addressing the issue of renewable energy development is progressively and tentatively negotiated and established. They constitute what Callon calls tentative "problematizations" of issues, that is "gradual process[es] of fragmentation and division of issues that evolv[e] into the joint formulation of a set of different problems which in a sense, at least partially, are a substitute for the initial issue" (Callon, 2009, p. 543). The engineering of markets which objectives go beyond the mere organisation of transactions effectively contributes to the breaking down of issues such as climate change mitigation or renewable energy development into "networks of problems" and to their provisional attribution to distinct institutions or categories of activities (Callon, 2009).

Talking of markets, then, is perhaps misleading. The establishment of market *agencements* is at the core of such processes of problematization, but these *agencements* in fact "combine devices that were previously attributed either to the economy or to expression and political action" (Callon, 2009, p. 544). Since they are emergent and experimental, carbon markets and renewable energy markets alike are characterised by redefinitions and reconfigurations of categories of problems and activities (such as markets, economics, politics, science and technology) that are perhaps more active, and certainly more visible, than they are in more stabilised market *agencements*.

2.2.2.2. Dealing with issues

These dynamics of problematization and (re)distribution of problems are driven by the overflowings and matters of concern they induce. The irruption of overflowings or matter of concern implies that effects that were previously unattended to turn into problems, sometimes to the point that they disrupt existing *agencements*. Elements that were formerly overlooked have to be taken into account. For Callon, this means that:

[81] It does share many similarities with the establishment of the EU carbon market. Climate and energy policy are increasingly linked at the European level, and the two processes (RE deployment and the reduction of greenhouse gas emissions) are structured in very similar ways, especially since they are addressed by the same sets of directives, the Energy-Climate Package.

> "A market which functions satisfactorily is one that organises the discussion of the matters of concern produced by its functioning and the framings/overflowings that it entails. It takes these matters of concern into account and sets up procedures and devices designed not only to encourage the expression of problems which arise but also to facilitate the design and evaluation of theoretical or practical solutions to those problems. A definition such as this, which grants centrality to on-going open experiments and to the debate and controversies accompanying them, closely links distinctly economic activities and those that one would tend to qualify as political and that markets tend to exclude from their ambit" (Callon, 2009, p. 541).

Callon's perspective, at least as far as this study of carbon markets is concerned,[82] remains centred on the functioning of markets, and considers these matters of concern in relatively abstract terms, that is without exploring in details the activities "that one would tend to qualify as political" (Callon, 2009, p. 541). How do matters of concern actually emerge as such? What are they made of? How are they dealt with? What does it mean to organise their discussion?

It is with such questions that the STS approach to markets meets studies on public involvement and issue formation, which precisely deal with the emergence, articulation and discussion of issues and matters of concern. The organisation of the discussion of matters of concern and of the role of public involvement in it is not a new field of investigation for STS (e.g. Barthe, 2009; Callon, Lascoumes & Barthe, 2001; Wynne, 1992; Latour, 2004 [1999]; Jasanoff 2011). However, it used to be relatively limited in scope for two main reasons. First, unsurprisingly, it has mostly considered the issue in relation to techno-scientific controversies, thereby focusing on a rather specialised area of policy-making. Second, as Marres and de Vries have remarked, it has tended to consider public involvement and matters of concern mainly in procedural terms (de Vries, 2007; Marres, 2007). Traditionally, the focus has indeed been mostly on the organisation of political discussion of scientific and technologic issues, and the inclusion of diverse actors and alternative forms of expertise in traditional deliberative procedures.

De Vries (2007) has argued that in so doing, STS have relied on an "off-the-shelf" conception politics, when it was equipped to propose alternative perspectives on politics and policy-making, and in particular to study policy processes as *practices*. In other words, STS research could "look at politics in the way [it] has learned to look at science: as a practice in which an object can circulate because a constitution has been put in place that comprises social, literary and material technologies" (de Vries, 2007, p. 796). He thus proposes to understand politics as turning around objects (and not subjects) and to redefine them as concerning "not a goal that is in the minds of subjects – not a matter of preferences, interests and plans – but what circulates in an association that has an appropriate constitution and is understood as an aim for *praxis*" (de Vries, 2007, p. 806).[83]

[82] In a related paper that focuses on the ways in which markets produce matters of concern, he considers a few examples of market overflows, and in particular the way in which "emergent concern groups" turn them into matters of concern that need to be addressed (Callon, 2007).
[83] De Vries goes back to Aristotle's definition of politics, and in particular to the distinction between *poiesis* (an action undertaken with the intention to produce some external end) and *praxis* (an action that aims at the activities themselves, which implies the collapse of the means/ends dichotomy). Classic political thought, de Vries argues, defines politics in terms of

A recent strand of research has thus extended the application of STS methods to the study of politics by focusing on their objects and their practices (Marres, 2005, 2007; Barry, 2001, 2002; Latour, 2007; Laurent, 2010; Lezaun, 2011). In this perspective, the interest in matters of concern (i.e. problematic, heterogeneous, non-stabilised entities that act in unpredictable ways) is not limited to the organisation of their discussion. Instead, this strand of research looks at their articulation into public problems. It is interested in the career of issues.[84]

Marres (2005, 2007) has shown that issues are formed and articulated by and along with the collectives and instances that are concerned by them and discuss them. She relies on a re-interpretation of pragmatist thought, and in particular of the debate between Lippman and Dewey over the role of the "public". The situations that the two pragmatists points to as requiring and triggering the emergence of publics in fact bear many similarities with matters of concern and with Callon's market overflowings. The public as Dewey defines it

> "consists of all those who are affected by the indirect consequences of transactions, to such an extent that it is deemed necessary to have these consequences systematically cared for. […] This supervision and regulation [of these consequences] cannot be effected by the primary groupings themselves. […] Consequently special agencies and measures must be formed if they are to be attended to" (Dewey, 1991 [1927], p. 15-16, as cited in Marres, 2007, p. 767-768).

For both Dewey and Lippman, **publics** come into play when existing institutions are unable to deal with unexpected, indirect consequences of previous actions, or, in Marres words, "publics come into being as an effect of changing consequences of human action, which existing institutions can't accommodate" (Marres, 2007, p. 769). An **issue** as defined by Marres thus starts out as a **set of (unintended) consequences that existing institutions are unable to settle**, thereby making public involvement and the experimental development of new forms of organisations and procedures necessary.

> "[Both Lippmann and Dewey] argue in favour of an experimental approach to public involvement in politics, in which new forms and procedures must be developed to address public affairs, and both justify this experimentalism by referring to problems that institutions can't contain." (Marres, 2007, p. 769)

However, Marres' goes further than Dewey and Lippman when she proposes to rely on the contributions of STS to investigate precisely *how* publics and issues are articulated. She stresses that they do not emerge fully formed. Their co-articulation is a costly and risky process, the success of which can never be taken for granted.

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poiesis, when a turn to politics as *praxis* could prove more fruitful. In terms of analytical perspective, this would mean a shift of focus from the intentions of political subjects to the objects of political *praxis*.

[84] In a response to de Vries (2007) and Marres (2005, 2007), Latour (2007) has drafted a framework for studying the political trajectories of issues, identifying five meanings of the word "political" that can describe distinct stages in the "life" of issues. Since I do not directly use this framework in the remainder of this dissertation, I have chosen not to discuss it in the annexes instead of the main text (cf. Annex 3).

The constitution of an issue and of the public concerned by it as well as the production of knowledge and information about it all proceed from the same movement, and cannot be separated. This dual movement is made difficult by two types of challenges. First, issues are often not directly visible, and usually not extensively documented. Indeed, they are problematic precisely *because* they have not been accounted for and attended to. Emerging issues thus need to be articulated, studied and documented, in short brought into concrete existence through a combination of material and discursive devices. As Callon wrote in his review of Barry's *Political Machines*,

> "*Mise en politique*, a convenient but somewhat deceptive expression, is in reality indissociable from the making of political issues, that is to say, from *the production of events that show the unexpected effects of overflows*, and particularly overflows linked to the sciences and the technologies." (Callon, 2004, p. 126-127, emphasis added).

Since issues overflow established institutions and procedures, this work of issue articulation at least partly involves members of the public. In Dewey's definition, the public is composed of all those that are affected and concerned by the issue. However, as Marres underlines, those jointly affected by the same issue are not necessarily affected in the same way (Marres, 2005). Far from being homogeneous and cohesive, an emerging public is "a community of strange things" (Marres, 2005, p. 66) whose members are more than likely to have different, if not utterly conflicting, interests. If the articulation of a public around an issue reveals anything, it is first the diversity of ways to be concerned by this issue and the entangled interests that gather around it and that were so far undocumented:

> "Articulating a public affair renders explicit, and thereby opens up for critical scrutiny, the mutual exclusivities between associations that different constituencies bring to a controversy, and which are caught up in the matter at stake, and a de-publicizing articulation can render such exclusivities obscure." (Marres, 2007, p. 773)

To "successfully" (at least in terms of public involvement) articulate a public affair then, "is to demonstrate for a given issue that, first, existing institutions are not sufficiently equipped to deal with it, and, second, that it requires the involvement of political outsiders for adequately defining and addressing it" (Marres, 2007, p. 772). This double requirement is not easy to meet. As Marres underlines, the articulation of an issue may just as well lead to its "de-publicization", that is to a re-organisation of institutions and procedures that addresses the issue but does so in way that obscures the diversity of interests and afflictions, thereby closing down the space for further discussions and disagreements.

2.2.2.3. Markets, politics, and the management of the unexpected

By focusing on how problems that challenge expectations and existing institutions and procedures are made into public issues, Marres develops an approach to politics that is centred on their objects. **Politics** are not defined as a set of procedures and institutions so much as the **practices that articulate emerging problems into public issues by organising their consideration, discussion and management**. Marres however stresses that the emergence of issues can take very different strategies; depending on how the co-articulation of an issue and its public occurs, spaces of disagreement and negotiation can be opened up or closed down.

Barry (2001, 2002) has developed a similar approach focused on the technicality, materiality and specific dynamics of politics, which he first defines as referring "to all those kind of institutions, agencies and practices broadly associated with international, national and local government" (Barry, 2002, p. 268). Like Marres, he stresses that objects and problems do not have "inherently political properties" but, instead, "may become more or less political" in different ways (Barry, 2001, p. 209). Importantly, for Barry, the adjective "***political***" should not be taken merely to mean "related to politics". Indeed, Barry makes a distinction between "politics", understood as a stabilised "set of technical practices, forms of knowledge and institutions" the role of which is "to contain and channel [dissensus and controversy] in particular directions" (Barry, 2001, p. 208), and "the political" as "an index of the space of disagreement" (Barry, 2002, p. 270) that is not reducible to politics. Much like Marres' emerging issues, the effects of an action are political "precisely in so far as they cannot be understood in the conventional terms of political discourses" (Barry, 2002, p. 270). What is **political**, then, is **what cannot be readily absorbed in the standard course of politics**.

In Barry's definition, **political action** opens up **new, unchartered spaces of disagreement** that the codified devices and conventions of politics are unable to channel and manage. **Politics**, on the other hand, comprise the **sets of institutions and procedure that codify and stabilise** the management of disagreement.

It follows that "politics" tend to place limits on the proliferations of spaces of contestations and confrontations; hence, they often have "anti-political effects" (Barry, 2002, p. 270). Barry further argues that this tension between political and anti-political dynamics, that is between the opening up of new spaces of disagreement and their containment and channelling, is constitutive of politics:

> "Politics, after all, is both about contestation, and the containment of contestation. It is about the possibility of governing *and* about questioning and disrupting the condition for government. It is about conflict, negotiation *and* the resolution of conflict. For government to be possible it is necessary to reach common decisions, however arbitrary, negotiated and provisional such decisions are. The fact that such common decisions have to be arrived at in the face of persisting disagreement and in the absence of 'rational' justification is one of the persisting circumstances of politics." (Barry, 2002, p. 270)

The symmetry with developments on markets and market *agencements* is striking.[85] Both Callon and Barry are indeed interested in *agencements* that organise and coordinate collective action, and in particular in two aspects of this coordination. First, they consider such *agencements* to be **constantly traversed by contradictory dynamics of disruption and structuration** and thus focus on the ways in which they manage the balance between – to use very broad terms – stability and change. Second,

[85] This is hardly surprising, as Barry and Callon explicitly refer to one another in the development of their respective lines of thought. For instance, Barry's 2004 paper starts out by writing that "the perspective adopted in *The Laws of the Markets* offers a good starting point. Callon argues that the discipline of economics tends to forget that the formation of markets is a technical matter, requiring extraordinary investments in the law, technology, architecture, accountancy and, sometimes, economics. Likewise, political scientists tend to forget the remarkable technicality of politics. […] The political actor does not come isolated into the political arena any more than the consumer comes isolated into the marketplace. He or she comes with a whole array of material devices and forms of knowledge which serve to frame political action" (Barry, 2004, p. 268-9).

they mean to qualify what makes these *agencements* and the forms of collective action they coordinate **distinctly "political" or "economic".** In so doing, they always consider the "political" or "economic" character of an *agencement* as an outcome of its organisation that is always contestable and reversible, at least in principle. Market *agencements* organise transactions involving monetary compensation. Symmetrically, political *agencements* could be defined as organising the discussion of disagreements over public issues. The similarities between the two approaches appear clearly when comparing the way Barry accounts for the (provisional) demarcation of "realm of public contestation" with Callon's definition of the shifting boundaries of markets and market *agencements* (cf. p. 94-95 above), as well as in the symmetry between Barry's distinction of "politics" from the "political" and Callon's conception of markets as depending on the balance between "exploration" and "exploitation" (Callon, 2010, pp. 166-167).[86] For Barry,

> "In politics the collective is not a given, but an entity in process. The fact that there is never likely to be a consensus about what the collective is and what individual rights and duties are does not prevent the emergence of a common view. Conversely, the need for a common view does not make the fact of disagreement evaporate. […] In general, legislation and technical regulation have the effect of placing actions and objects (provisionally) outside the realm of public contestation, thereby regularizing the conduct of economic and social life, with both beneficial and negative consequences. The divisions between the realm of political contestation, on the one hand, and the realms of law, administration, science and the economy, on the other, are always temporary and, in principle, constestable" (Barry, 2002, p. 271).

[86] Callon thus explains: "Exploration can be likened to the creation of a more or less new market which, once stabilized, is dominated by exploitation organized around well established interests, preferences, competencies, as well as stabilized, framed calculations and routines. Exploitation, on the other hand, is structured around activities of mobilization and allocation of resources identified precisely and defined in a (relatively) stable way. Any market is caught in this tension between exploration and exploitation, between on the one hand its renewal and its reconfiguration, and on the other its reproduction. […] The type of balance that is sought between those two requirements (designing new products *versus* rationalizing the production and distribution of existing ones) is a key question for market design. Its answers strongly influence their capacity to renew and extend the world of available goods – what used to be called wealth and which contributes to the constitution of what is now called the common world. This is a profoundly political issue; even one that is doubly political if we refer to what was said above. First, it points to the definition of a market that functions well, that is, one that maintain a balance deemed to be acceptable (according to which criteria?) between exploration (breakthrough innovation) and exploitation (incremental innovations) or, in other words, between the investigation of possible worlds and the gradual extrapolation of those that exist. Second, it concerns the nature and qualification of the goods needed by the various groups and agents, and consequently the mechanisms that organize the exploration of needs." (Callon, 2010, pp. 166-167)

Table 8 Market and political *agencements*

	Lines of stratification	Lines of actualisation
Market agencements	Lock-in Framing of goods, agencies and transactions Stability required for economic agents to engage in activities	Innovation Autonomy of economic agents Unpredictability of economic goods
Political agencements	Institutions, codified procedures Channelling of disagreement and containment of contestation	Co-articulation of publics and issues in the face of matters of concern

The difficulty in analysing FIT-driven photovoltaic markets lies in the fact that, like carbon markets, they explicitly combine markets and politics. To complicate the matter, neither photovoltaic markets nor photovoltaic politics are currently stabilised. In such a context, how to account for the interweaving and co-production of market *agencements* and political *issues* without obscuring their differences? Both are faced with the similar challenge of maintaining a degree of stability that permits – and triggers – changes and innovations, and the organisation and respective roles of market and political *agencements* are fluctuating. Yet, the politics and the economics of photovoltaics remain clearly distinct, as is clear in the accounts of the actors involved, and as the moratorium crisis has demonstrated in a striking manner (cf. Chapter 4 below).

Provided that this line is treaded carefully, because of the ambivalence of FIT schemes, the study of photovoltaic markets can shed light on two points that are precisely at the intersection of market studies and politics studies as approached in STS research.

First, feed-in tariffs for PV-generated electricity can be analysed as **devices that equip both agents and things with not only economic but also political capacities**. This extends an already long line of work on the framing of economic agencies (Callon, 2008; Hardie & MacKenzie, 2007), as well as a more recent one that focuses on engagement devices and the materiality of political participation (Marres, 2011, 2012, 2013; Marres & Lezaun, 2011). In the latter strand of research, the question is "how objects, devices, settings and material acquire explicit political capacities, and how they serve to enact material participation as a specific public form" (Marres & Lezaun, 2011, p. 489). It is thus interested in the way material devices confer political capacities, as well as in how they can be explicitly endowed with political capacities of their own. This equipment, as that of economic agencies, has to be performed, as Marres pointed out:

> "For no entity, whether human or non-human, institution or thing, it suffices to posit on theoretical ground that they 'have' political capacities. For all entities, *agential capacities depend at least in part on how these entities are equipped – on the configuration of an assemblage of entities that enables the explication of their normative capacities*. This is why, somewhat paradoxically, in order to grasp the politics of objects, we must pay attention not just to objects, but also to *the technologies and settings which enable them to operate*. We must investigate *how particular devices make possible the investment of things with political capacities*. Or to say this in yet another way: it is not just that things and devices enable a performative politics, in the sense that they facilitate the enactment of particular political phenomena, say 'participation'. The investment of things and devices with normative capacities itself must be understood as a performative accomplishment just as well." (Marres, 2012, pp. 104-105, emphasis added)

FIT schemes are meant to trigger economic transactions but also, in a more or less explicit manner depending on how they are designed, to encourage a form of political participation that is mediated through the installation of – very material indeed – photovoltaic systems. Photovoltaic devices, hard to predict and frame as they have turned out to be, can be considered as active players in the process, from both an economic and a political perspective. Through the combination of the modularity of photovoltaics and of the diversity of modes of engagement that FITs make possible, actors involved in photovoltaic projects find themselves in position to participate in innovation in technologies, but also in economic models, territorial development, or policy-making (though with varying degrees of success).

Second, as FIT schemes are, in large part, devices for price formulation, their study can address the ambivalence of practices of calculation and of the calibration of political/market instruments. Calculation and market regulation have often been regarded as "antipolitical" or depoliticising practices, in that they take matters away from political discussions and public arenas (Barry, 2002, p. 272; Muniesa 2010). Barry has challenged this conception of calculation and metrology, stressing that in some cases, it can actually make visible unexpected events and contribute to turning them into issues, thereby producing political effects (Barry, 2002). In the case of feed-in tariffs for PV-generated electricity, it is clear that calculation and formulas can be considered neither as political nor as antipolitical. Their political or antipolitical character depends on how they are arranged. In other, FIT schemes can be equipped with political capacities (that is, capacities to generate innovation and organise space for the deployment and confrontation of a plurality of interests, agencies and engagements with photovoltaics) or, on the contrary, be turned into automatic, self-regulating market devices (that obscure and frame out the expression of contestations). Further, it is in large part through the formulas that FITs rely on that agents and things are invested with political and/or economic agency or deprived of it. Feed-in tariffs for PV-generated electricity can thus be analysed as powerful engagement devices, the design of which can determine what and who will be activated and what types of actions will be facilitated. As the rest of this thesis will show, this dimension is more or less explicit depending on how FITs are designed *and* seized. The degree to which FITs have evolved and been reconfigured throughout a relatively short period of time suggests that this is the heart of the battle.

Interlude

A description of FIT-photovoltaics *agencements*

In the previous two chapters, I have reviewed key ANT concepts and relied on them to define the deployment of FIT-supported photovoltaics as an object of research. In chapter 1, I have focused on the methods employed by ANT to describe entities in-the-making and on the specific conception of action and agency that follows. From an ANT perspective, entities and action are in fact closely related and mutually constituted; both are relational, heterogeneous, constituted and multiple. It follows that entities cannot be described as substances, but have to grasped through the effects they produce and through the practices that enact them.

In chapter 2, I have extended and refined this approach to action by relying in particular on the notion of socio-technical *agencement* (Callon, 2013). *Agencements* are heterogeneous combinations of human beings, discourses and knowledge, and technical devices considered in terms of their capacity to act and to trigger action. A crucial characteristic of *agencements* is that they are always caught up between the structures that they frame and the dynamics that they spark and that carry them away: to phrase it in terms proposed by Deleuze (1989), *agencements* articulate "lines of stratification" (that tend towards stabilisation and incorporation into existing institutions) and "lines of actualisation" (that tend towards novelty and disruption).

This conceptual background enabled me, on the one hand, to qualify photovoltaic technologies as emergent and modular and, on the other hand, to define feed-in tariffs as political and market *agencements*. What does such a perspective imply for the description of recent evolutions in photovoltaic markets and politics? How do feed-in tariffs as *agencements* seize the modularity of photovoltaics? Putting together the conclusions from the first two chapters of this dissertation can shed a new light on feed-in tariffs for PV-generated electricity.

As outlined in chapter 1, photovoltaic technologies are primarily defined by the *effect* that they perform, that is to say by the fact that they rely on the photovoltaic principle to generate electricity from light. Since this effect can be performed in various manners (both using a wide variety of combination of material and arranging different systems), photovoltaic technologies are by definition a heterogeneous set whose limits cannot be fixed *a priori* and in definite terms. The modularity of photovoltaic technologies as I have defined it points precisely to their ability to be arranged in many ways while producing the same effect. In other words, because they are modular, photovoltaic technologies are at one and the same time stabilised interfaces between the sun and the grid performing a constant function, and active mediators that can be assembled in many ways and attached to a wide variety of collectives, political objectives, business models and material structures.

Further than that, the modularity of photovoltaics enables them to proliferate, and in that it is different from the "fluidity of technology" as defined by de Laet & Mol (2000). A “fluid technology” is one that can adapt to diverse environment while retaining the same function(s) – and in that sense, photovoltaic systems are “fluid”. But “fluid technologies” such the Zimbabwe bush pump for which the concept was coined are displaced and customised as unities, whereas photovoltaic modules can be assembled together at the scale of a single photovoltaic installation or plants, but also at the scale of the electricity grid to which they are connected. Modularity thus implies a potential for multiplication and amplification of the effects of photovoltaics. It follows that it can trigger quantitative as well as qualitative overflows, making the development of photovoltaics twice as difficult to steer.

Feed-in tariffs, as I have described them in chapter 2, work by acting on two aspects of photovoltaic technologies (cf. Fig. 9). By framing transactions of the electricity generated by photovoltaic systems, they constitute photovoltaic electricity into a tradable (hence stabilised, pacified) economic good, thereby treating photovoltaic systems as silent intermediaries. However, the opportunity that this framing provides is meant to create a protected space allowing for innovation, learning and bricolage around photovoltaic systems so as to ultimately enhance their efficiency and competitiveness. Feed-in tariffs make sense until photovoltaic electricity reaches grid parity, i.e. becomes a viable economic good in independent market *agencements*, and they are meant to make grid parity happen sooner by triggering transformations in photovoltaic technologies and arrangements.

But, on top of articulating this tension between stabilisation and actualisation, the good functioning of a feed-in scheme requires that it work as a market *agencement and* as a political *agencement.* To function as market *agencements*, feed-in tariffs have to frame economically interesting transactions, that is chiefly to guarantee a fair price for photovoltaic electricity. To function as political *agencements*, they need to strike an acceptable allocation of risks and powers, and to articulate the various concerns raised by those concerned by their effects. The tension between lines of stratification and lines of actualisation in feed-in tariffs for PV-generated electricity is thus at play on several levels, which is why, I argue, it is interesting to consider them as *agencements*, and also why their calibration is such a crucial – and complex – matter.

The following chapters consider different dimensions of feed-in tariffs for PV-generated electricity as market and political *agencements*, or rather as experimental *agencements* that articulate political objectives and capacities *and* market transactions. As will be explored, feed-in tariffs determine who can benefit from the development of photovoltaics and to what extent, and who should have a say in steering it; and they frame market agencies and price formulation on the market for photovoltaic electricity (this is for the “stratification” part). They also endow specific (but not necessarily predetermined) things, organisation and people with political agency and/or with market agency, providing them devices for innovating and – potentially – overflowing. In that sense, their ambivalence means that what is at play in the design and calibration of feed-in tariffs is not only the balance between inventiveness and stability, but also the negotiation of the distribution between what should be considered as politically relevant and what is to be delegated to market transactions and regulation.

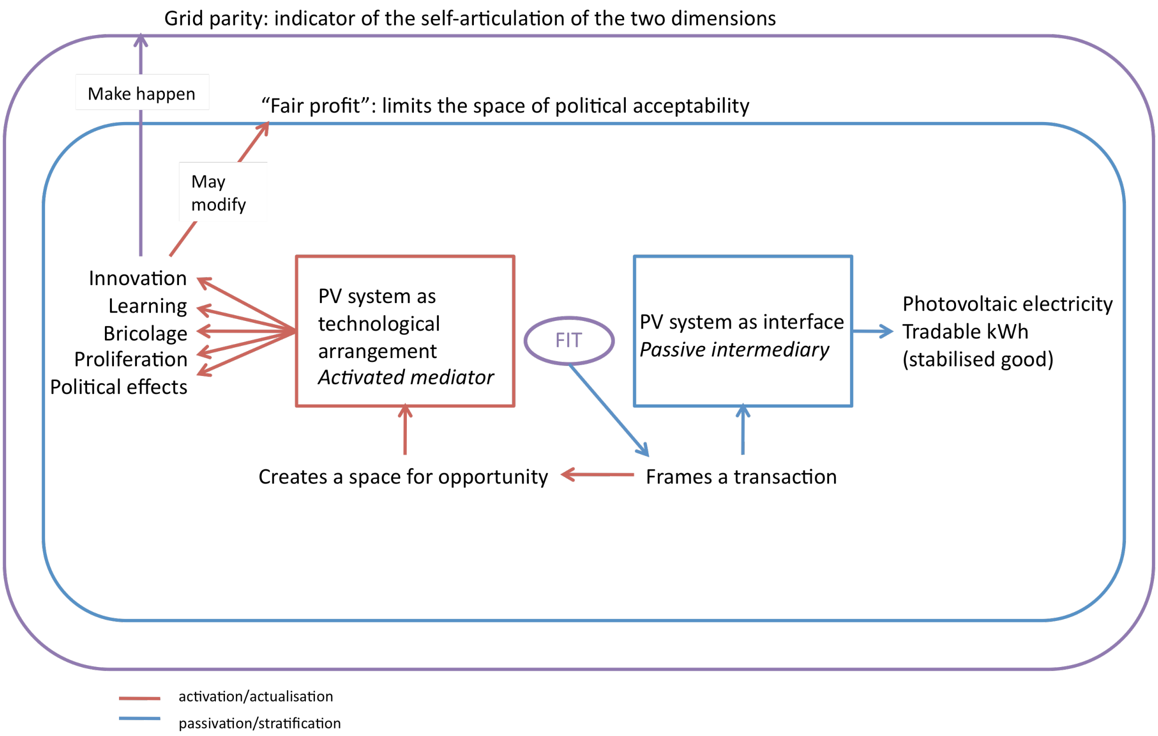

Figure 9 The dual effects of feed-in tariffs on photovoltaics

Chapter 3

The career of feed-in tariffs in the European Union

> "FITs can be very simple […] or they can be quite complex."
> IPCC—*Special Report on Renewable Energy*

Feed-in tariffs as *agencements* of photovoltaic markets and politics, their relations to photovoltaic technologies and their effects are at the heart of this dissertation. Where do feed-in tariffs come from? How were they constituted as a specific type of political and market *agencements*? And how have renewable electricity markets and politics been articulated around feed-in tariffs?

The focus on the instruments that support photovoltaic development is justified insofar as the increase in photovoltaic capacity and investments has been driven by active policies to this end, especially in Europe. The creation of photovoltaic markets directly results from decisions aiming to increase the share of renewable energy in Europe. The history of photovoltaic markets is closely tied to that of the policies and instruments that they rely upon. Since these have emerged at the level of the European Union (EU), their history cannot be entirely separated from the evolution of European renewable energy policies and markets in general.

The objective of this chapter is to understand the conception and development of feed-in tariffs – the most widespread instruments for promoting photovoltaic power today – as part of the policy arsenal developed to spur the creation of renewable energy markets in Europe.[87] Several reasons justify this European focus. First, since renewable energy production objectives have been set at the EU level (Commission of the European Communities, 2001; 2009), French renewable energy policy cannot be considered independently from the EU context. Second, the development of market-based instruments to support electricity from renewable energy sources (RES-E) is in many ways a European endeavour: it draws on experiments and initiatives in several EU countries, as well as on objectives, frameworks, surveys and assessments developed at the EU level, and on academic works informed by and informing these processes. The interactions between national support schemes, European debates, and academic

[87] The term "Europe" here includes the European Union and individual European countries.

literature appear crucial to understand the creation of RES-E markets at the intersection of politics, economics and knowledge production.

In this chapter, I consider mainly two aspects of the European career of feed-in tariffs. First, I look at the emergence, constitution and evolution of feed-in tariffs (and, more broadly, RES-E markets and policies) as a process of collective, scale-one experimentation monitored by European institutions – at times explicitly, at times not. In this perspective, this case study points to the co-elaboration of market and policy devices and of the expertise and knowledge about them. It also highlights the difficulty in maintaining a clear distinction between agency and device, or between "cook and recipe" when studying the making of economic instruments (Holm & Nielsen, 2007).

Second, I analyse the elaboration and sophistication of feed-in tariffs in the light of the changes in status of these instruments. In particular, I stress the oscillation between moments of stabilisation (or stratification) and moments of disruption (or actualisation) in the career of feed-in tariffs. Depending on how they are designed and implemented, feed-in tariffs can spur economic and technological innovation and trigger political mobilisations or crises; they can be used in attempts to close down the space for political contestation by leaving everything to the market, to correct market failures, or, on the contrary, can be criticised for constituting direct political "tinkering" with the functioning of markets. They have, indeed, been alternately praised and criticised for all of these reasons according to how they deployed at specific moments. This chapter explores these evolutions in order to shed light on the complexity of feed-in tariffs as political market *agencements*.

To do so, it builds on the collection and analysis of documents pertaining to the promotion of RES-E in Europe that were published since the 1990s, as well as on a chronology of renewable energy policies in the EU and in a set of selected European countries (chiefly Denmark, Germany, Spain, Italy, France). This material was collected using a "snowball method" and is by no means exhaustive. It nonetheless allowed me to establish parallel timelines that trace the evolution of the issue of RES-E development in policies, European legislation, grey literature and academic research. This chapter is thus mainly based on document analysis. Within the frame of this dissertation, given the choice to span the history of feed-in tariffs in Europe rather than to analyse the details of European policy-making, I do not fully consider the complexity of the development of EU renewable energy policy. The internal workings of European institutions – the study of which would most certainly enrich the analysis – are thus not accounted for here.

The chapter is divided in four parts, which corresponds to four periods in the history of feed-in tariffs at the European level. The first period extends from the late 1970s to the mid-1990s and relates the emergence of "proto-feed-in tariffs" schemes in Germany and Denmark as means to take renewable electricity production into account. In this period, feed-in tariffs turned from a device to integrate renewable electricity in conventional electricity markets into a means to actually modify electricity markets by supporting the development of renewable electricity generation.

The second period, which corresponds to the second half of the 1990s, relates how the integration of the internal electricity market turned from a blueprint for EU renewable energy policy into a distant ideal as actual RES-E support schemes developed in

Member States: the increasing diversity of national policies made the EU-wide harmonisation that market integration implied harder and harder to achieve. In 1996, EU renewable energy policy revolved around the achievement of the internal market for electricity; in 2000, it was articulated around the development of market instruments such as tradable green certificates (TGC) or feed-in tariffs.

The third period, from 2000 to 2008, is a moment of explicit scale-one experimentation steered by European institutions in order to improve RES-E support instruments. I describe how this process drove the constitution of expertise and research on RES-E support and markets and the organisation of a "network of experimentation with markets", that is to say of a network allowing "for the joint and coordinated advancement of knowledge and theoretical models on markets, on the one hand, and of market materials and institutional devices, on the other" by structuring the interaction between sites of "in vivo" and "in vitro" experimentation (Callon, 2009). Feed-in tariffs were refined and theorised along the way.

The fourth and last period starts in 2008 and is more narrowly focused on support to photovoltaic power. In recent years, I show, problems with feed-in tariffs have emerged and have drawn attention to previously overlooked aspects of the instrument. Controversies have thus arisen on both political and economic grounds.

Section 1 – 1970s-1996: Taking electricity from renewable energy sources into account

1.1. Accommodating electricity from renewable energy sources: towards feed-in tariffs

The need to accommodate renewable energy into existing energy markets emerged in the late 1970s, mainly from the development of small-scale wind power. Mechanisms for feeding renewable electricity in the grid and remunerating it were crafted then to facilitate the integration of new forms of electricity generation. Initially, they were designed to allow electricity from renewable energy sources (RES-E) to blend into existing markets: tariffs were first defined in relation to "the avoided costs of fossil fuels" in an attempt to make RES-E equivalent to conventional electricity, and later calculated on the basis of average sales price for electricity. However, what started as market arrangements gradually turned into policies that increasingly aimed at promoting RES-E, until the European Union began to define renewable energy development into a political objective.

The first "FIT-like" mechanisms were designed and implemented in the late 1970s in the form of avoided costs payment schemes. In the US, they were introduced by the 1978 Public Utility Regulatory Policies Act (PURPA), which required that electric utilities purchase electricity produced by "qualifying facilities" (i.e. certain small-scale electricity producers) at prices that reflected their long-term avoided costs (Lesser and Su, 2008, p. 982; Loiter and Norberg-Bohm, 1999). "Avoided costs" were calculated by state Public Utility Commissions using varied methodologies (Loiter and Norberg-Bohm, 1999).

Some were established on the basis of forecast models of future fossil fuel and electricity prices, which turned out to lead to them being overestimated (Lesser and Su, 2008).

In Europe, mechanisms based on the principle of avoided costs appeared around the same period to deal with the development of wind power production in Denmark and Germany.[88] In both countries, these mechanisms emerged in the late 1970s from the need to regulate the integration of wind power to the grid, at a time when it started developing. Until the early 1990s, they did not rely on government regulation but on regularly renegotiated voluntary agreements between electric utilities and wind power producers.

1.1.1. Denmark

In Denmark, investment subsidies for wind turbines were created in 1979. By then, wind power was mostly developed by neighbourhood cooperatives (Meyer, 2004, p. 28), and "utilities had little experience in handling dispersed, small-scale electricity systems such as wind turbines" (Meyer, 2004, p. 28). To accommodate the resulting development of wind power, a first agreement was signed in 1979 under governmental supervision between the Association of Danish Electric Utilities and the Danish Wind Power association together with Danish wind turbine producers (Evrard, 2010; Meyer, 2004). Utilities thereby agreed to purchase surplus electricity from wind power producers and to feed it to the grid at a price lower than that paid by consumers and determined on the basis of avoided fuel costs (Evrard, 2010, p. 212).

Under pressure from wind power producers, the agreement was renegotiated several times in the 1980s. In 1984, a new voluntary agreement stated that utilities were to pay for 35% of grid connection costs for wind power, and to purchase wind power surplus at a rate of 85% of retail price (Evrard, 2010, p. 213). In 1992, the government eventually introduced legislation regarding the grid connection of wind power and establishing feed-in tariffs, following the same mark-up model: the tariff was fixed at 85% of the utility production and distribution costs. The addition of a tax refund allowed for returns on investment of 10 to 15% for wind power project, which was high enough to yield growth in installed capacity (Meyer, 2004, p. 28).

1.1.2. Germany

The emergence of support for RES-E in Germany followed a similar path. The difficulties encountered in the 1970s by wind power producers to sell their surplus electricity led to the signature of an association agreement between the electric industry associations *Verband der Elektrizitäswirtschaft* (VDEW), *Verband der Industriellen Energie und Kraftwirstschaft* (VIK) and *Bundesverband der Deutschen Industrie* (BDI) in 1979 (Lauber and Mez, 2004, p. 600). As its Danish counterpart, it obliged electric utilities to purchase RES-E according to the principle of avoided costs. It was however interpreted in a restrictive way by utilities, leading to a much less generous framework

[88] "Avoided costs" based mechanisms were also used for co-generation for instance in Italy and an France (Interview 39).

than that provided by the PURPA in the US (Evrard, 2010, p. 246-247; Lauber and Mez, 2004, p. 600).

The German Minister for the Economy was reluctant to provide incentives for the formation of markets for renewable energy, judging them to rely on non-mature technologies (Evrard, 2010, p. 247). However, by the late 1980s, there was a growing consensus in Parliament "that it was time to create markets for renewable energy technologies" (Lauber and Mez, 2004, p. 601); support programmes such as the 100/250 MW wind programme and the 1,000 solar roofs programme were created, and proposals to establish feed-in tariffs for RES-E were formulated (Lauber and Mez, 2004).

The *Stromeinspeisungsgesetz* (StrEG), or Feed-in Law, was eventually adopted in 1990. Moving away from the principle of avoided costs,[89] it set feed-in rates designed to reflect the external costs of conventional power generation (fossil fuels and nuclear) in order to level the playing field between different sources of electricity (Lauber and Mez, 2008; Lipp, 2007, p. 5488). Under this law, utilities were required to connect renewable energy generators to the grid and to purchase it at 65 to 90% of the price paid by consumers, in the same logic as the Danish system.

In both countries, the feed-in tariff proved effective in stimulating market formation for renewable electricity, and especially in promoting wind power. From 20 MW in 1989, installed wind power capacity grew to over 1,100 MW in 1995, a direct effect of the StrEG (Lauber and Mez, 2004, p. 602). This, however, did not happen without raising opposition from conventional electricity generators. Utilities turned to judiciary action at several levels (Länder, EU…) in attempts to roll back the law. In 1996, VDEW filed a complaint to the European Commission's Directorate General in charge of competition (DG Competition), invoking violation of state-aid rules (Lauber and Mez, 2004, p. 603).

1.2. The development of renewable energy as a European concern

Meanwhile, the EU had started to consider renewable energy issues. Following its Resolution of 16 September 1986 concerning new Community energy policy objectives for 1995 and convergence of the policies of the Member States (European Council, 1986), the European Council issued a Recommendation on developing the exploitation of renewable energy sources on 9 June 1988 (European Council, 1988).

After confirming the 1986 "objective of continuing the development of new and renewable energy sources and of increasing their contribution to the total energy balance", the Council stressed that the "development of renewable energy source requires appropriate legislative, administrative and financial measures", and recommended Member States "to introduce, where appropriate and necessary, legislation and/or administrative procedures which would help to overcome, on a non-discriminatory basis, obstacles to the exploitation of renewable energy sources" (European Council, 1988). The Council Resolution of 13 December 1993 concerning the promotion of renewable energy in the Community, which created the Altener

[89] In 1989, the Framework for electricity tariffs was modified so as to allow for compensation of RES-E generators above avoided costs (Lauber and Mez, 2004, p. 601).

programme, further confirmed the consideration of the issue of RES-E development at the EU level.

When the StrEG was notified to the European Commission for approval under state-aid provisions, the Commission decided not to raise any objections "because of its insignificant effects and because it was in line with the policy objectives of the Community" (Lauber and Mez, 2004, p. 602), but planned to reconsider the matter two years later. However, by the time VDEW lodged its 1996 complaint, the Commission was beginning to worry that feed-in tariffs might provide "excessive" minimum prices for wind power, given technological evolutions since 1990 (Lauber and Mez, 2004). In a letter to the German Government following VDEW complaints, the Commission thus "expressed doubts about the continued compatibility of the *Stromeinspeinsungsgesetz* with the Community State aid rules.

The greatest concern was caused by the calculation of the minimum purchase price for electricity generated from wind" (Jacobs, 2000, §19). The Commission was particularly worried that a minimum purchase price markedly higher than the cost of wind power generation might distort competition between Member States, and thereby prove incompatible with the Common Market. It proposed alternative methods for fixing the level of the minimum purchase price that would restore the compatibility of the StrEG with State aid rules, that the German Government did not follow: "reducing the minimum purchase price for wind electricity, limiting the support mechanisms in time and/or according to electricity production, or calculating the purchase price on the basis of avoided costs" (Jacobs, 2000, §21).

Throughout the 1980s and early 1990s, the mechanisms designed to frame RES-E in the same terms as conventional electricity so as to integrate them into the electricity grid and markets led to their gradual inclusion into the scope of energy policy. In the early 1990s, renewable energy was increasingly taken into account for its specificities. Renewable energy was gradually incorporated into the scope of general interest, and, instead of making renewable energy sources equivalent to conventional energy sources, the objective became to develop them *because* they were not the same.

Section 2 – 1996-2000: The internal electricity market, from a blueprint to an ideal

During the second half of the 1990s, European renewable energy policy developed in two ways. On the one hand, several countries had put in place – or were starting to put in place – policies to promote renewable energy; on the other hand, the European Union elaborated the principles for an EU-wide framework for renewable energy, articulating a Common Market, innovation and environmental protection. This occurred at a point when setting up the internal market for electricity was on top of the EU agenda in the perspective to effectively realise a Common Market: the EU renewable energy policy was supposed to help achieve market integration in the energy sector. Therefore, support to renewable energy was justified because and to the extent that it could contribute to the correction of market failures without creating additional distortions. The benchmark for RES-E support was then the external costs of electricity production: renewable energy policies were supposed to contribute to their internalisation and to the correction of the failure of market to take into account the lower external costs of electricity from renewable energy sources. When defining its renewable energy strategy, the EU thus sought to determine common rules able to ensure that RES-E support policies remained compatible with the principles and expected operation of a harmonised, integrated internal electricity market that still was only a project.

2.1. Renewable energy, innovation and the European internal market in electricity

2.1.1. Electricity from renewable energy sources in the context of market integration

2.1.1.1. An energy policy for an European internal market in electricity

The mid-1990s constituted a pivotal moment for EU energy policy. The directive 96/92/EC concerning common rules for the internal market in electricity (European Parliament and Council, 1996) was adopted in December 1996. It is an obvious milestone in the recent evolutions of the European electricity sector. The issue of renewable energy development was addressed in the course of the debates on European energy policy that surrounded the elaboration of the 1996 directive. It moved up the agenda in 1996, when the publication of a Green Paper on Renewable Energy Sources (Commission of the European Communities, 1996) launched a process aiming to effectively increase renewable energy use in the EU.

The bases of the European approach to renewable energy deployment had already been sketched in previous documents, including the 1993 White Paper on "Growth, Competitiveness and Employment – the challenges and ways forward into the 21st century", which considered "clean technologies" to be key for future economic prosperity, and articulated competitiveness and environmental protection as complementary (Commission of the European Communities, 1993), and the 1995 Green and White Papers on Energy Policy (Commission of the European Communities, 1995a, 1995b).

The latter clearly outlined the logic along which the European Commission was viewing support to renewable energy: environmental protection, technological development and competitiveness can go hand-in-hand, and they should be articulated through the operation of a common, liberalised European energy Market. Developing a functioning internal market was the core focus of the European Community, and, it follows, what an European response to energy policy challenges should revolve around: as the 1995 White Paper stated, "market integration is the central, determining factor in the Community's energy policy" (Commission of the European Communities, 1995b, p. 3).

To work "with the market rather than against it" (Commission of the European Communities, 1995b, p. 31), the Commission advocated the "internalisation of external costs and benefits" (p. 31), especially when it came to environmental concerns, but also to technological innovation. The White Paper thus considered that "a significant proportion of new technological development will be driven by environmental considerations" (p. 13), and chiefly by the growth of renewable energy.

The internalisation of externalities can justify support programmes or subsidies that help renewable energy to "find a place in the market" (p. 18) and technological developments to be translated into market products. To be as little harmful to competition as possible was a key requirement for the acceptability of support mechanisms.

2.1.1.2. Supporting electricity from renewable energy sources to improve the internal market

In fact, the Commission's approach to the development of electricity from renewable energy sources echoed contemporary reflections in academia about the interactions between policy, environmental protection and support to technological development (Jaffe and Stavins, 1995; Wiser and Pickle, 1998; Norberg-Bohm, 1999). This literature conceived innovation in green technologies as a means to achieve better environmental protection; one way of fostering innovation in those sectors was to design incentives that made investments in green technologies competitive, thus creating markets for technological innovations.

The notion that environmental protection and technological development ought to be achieved along with the operation of a liberalised market has indeed been very influential in the conception of RES-E support instruments in the EU. It implies a specific articulation of politics and markets. In such a perspective, policy intervention is acceptable only insofar as it constitutes a provisional correction to "market failures". Support policies are supposed to expire once they have fulfilled their duty to re-establish the "real", "unbiased", "level" operation of the market. Since they are conceived as "corrective" devices, these policies should generate as little additional distortions as possible.

As far as renewable energy is concerned, the existing distortions that policy interventions should suppress are the failure of the market to take into account environmental externalities and innovation externalities, and the resulting non-level playing field between conventional and renewable energy sources: incumbent energy sources benefit from artificial competitiveness resulting from the failure to take into account all of their hidden costs, as well as from institutional barriers and lock-ins (Unruh, 2000, 2002).

As a result, considering that the absence of RES-E from the market stems from existing "failures" or "imperfections", the purpose of RES-E support is to increase the generation of electricity from renewable energy sources through the deployment of renewable energy technologies. The history of the constitution of renewable energy policy indeed shows that the most frequently chosen path to achieve this purpose is to design policies that can help renewable electricity and technologies to enter the market and stay on it.

Based on the premise that renewables are not yet competitive with conventional electricity sources, this translates into establishing conditions that can reduce the difference between the costs of renewable and conventional energy, thereby reducing the differential in competitiveness. In short, “the basic premise of all renewable energy development policies is that they create demand that otherwise would not exist at desired levels under current market conditions” (Lesser and Su, 2008, p. 983, my underlining). This has developed into the creation of policy-driven and policy-sustained markets[90] meant to temporarily protect renewable energy.

2.1.1.3. “Revealing the ultimate performance” of renewable energy technologies

In an economics perspective, this “correction” of market conditions by public intervention “may therefore be theoretically justified in two main ways: internalisation of environmental externalities and stimulation of technological change” (Ménanteau et al., 2003, p. 55). The first justification calls for a “levelling the playing field” either through the internalisation of the external costs of conventional electricity production – for instance using climate mitigation policies such as a carbon tax or the EU ETS, or by setting subsidies that reflect the positive environmental externalities of renewable energy. Defining the right proxies for these externalities is quite complex, and different logics have prevailed over time. Initially, calculations were based on the specificities of fossil fuels, since renewable energy sources were supported at the “avoided cost of fossil fuel”. As renewable energy policies developed, however, support was increasingly designed according to the specificities of renewable energy sources.

The second possible theoretical justification for correcting the market, i.e. the need to stimulate technological change, translates into support that can help spur decreases in the cost of renewable energy by accelerating innovation and learning processes until they reach competitiveness. The two justifications are actually closely related: supporting technological innovation in renewable energy technologies (RET) until they reach economic maturity is supposed to eventually level the playing field. The development of renewable energy technologies may indeed contribute to changing current knowledge, routine and practices in energy markets and institutions, as much as to making renewable energy technologies competitive with incumbent energy technologies. In fact, in this logic, innovation in renewable energy technologies needs to be stimulated and supported because the failure of the market to take into account externalities hinders the innovation processes that would bring renewable energy technologies to the market under “unbiased” conditions.

Increasing the share of electricity from renewable energy sources in the energy mix to reduce the environmental impact of energy production is certainly one of the objectives of RES-E support, but it is not its ultimate objective. Above all, support to the deployment of renewable energy technologies on the market is expected to “stimulate a

[90] Some analysts call them “artificial market[s]”, given that they are not based “on the voluntary decision of the consumers/voters” and “rely on a command and control approach of a planned economy” (Haas et al., 2011). Their “artificiality” as defined by economic theory stems from the fact that they rely on a demand and/or a supply that are not stabilised yet – for instance, Sanden and Azar (2005, p. 165) state that “government supported market formation has proved to be critical when a private demand for a product has yet to be formed […] or when costs need to be brought down to be competitive on commercial markets”. This makes RES-E support instruments objects that are particularly suited to the study of marketisation processes, since they can be understood as proposals of ways to form and stabilise a supply and a demand that are not here yet [not functional yet].

dynamic process that will reveal their ultimate performance" (Ménanteau et al., 2003, p. 57). In turn, this process is supposed to lead to the correction of externalities, in particular of environmental externalities due to the use of fossil fuel.

This idea that policy-driven market deployment will accelerate innovation and trigger the cost reductions needed to make RES-E "a normal industry without special treatment" (Lauber, 2004, p. 1413) is crucial to the conception of RES-E support schemes. It originates from the "learning-by-doing" literature in economics that emerged in the mid-20th century (Wright, 1936; Hirsch, 1952; Arrow, 1962; Alchian, 1963 [as cited in Papineau, 2006]), and particularly draws from the learning curve or experience curve concept (Papineau, 2006; Jamasb, 2007). In their most common form, these concepts "define the cost or price of a technology as a power function of learning source in cumulative form such as installed capacity, output, or labour." (Jamasb, 2007, p. 54). In short, "they provide a simple quantitative relationship between cost and the cumulative production of a technology" (Papineau, 2006, p. 1). This relationship is measured by a "learning factor" which corresponds to the cost reduction for a given cumulative output.

These concepts were originally devised in the context of manufacturing and mature industries (Jamasb, 2007) and spread by the Boston Consulting Group in the 1960s as a tool to advise on competitive strategy (Papineau, 2006, p. 2). Papineau explains that the concept attracted newfound interest in the context of the development of climate change policies, but that its focus shifted from production planning and strategic management to "endogenous technical change an the use of reliable estimates of technological learning rates as inputs of energy forecasting models" (Papineau, 2006, p. 2, citing McDonald and Schrattenholzen, 2001).

2.1.2. Designing renewable energy policy for the European Union

2.1.2.1. A European strategy for the development of renewable energy sources

The European Community reaffirmed its will to design a renewable energy policy with the publication of the Green and White Papers on Renewable Energy Sources in 1996 and 1997, respectively (Commission of the European Communities, 1996a, 1997). The Green Paper drafted a political strategy articulated around four axes: a quantified target for increasing the share of renewable energy sources (RES) in energy consumption (namely its doubling by 2010), reinforced cooperation between Member States, reinforced European Community policies affecting RES development, and reinforced evaluation and monitoring of progress.

To do so, it drew on previous EU documents and legislation regarding renewable energy, as well as on evaluations of the technical and economic potential of renewable energy and renewable energy technologies, and on a range of recently published energy scenarios.

The 1996 Communication from the Commission "European energy to 2020: a scenario approach" provided an exploration of four possible paths for the energy sector without specific renewable energy policies (Commission of the European Communities, 1996). It refers to the studies TERES and TERES II explored additional scenarios that took into account renewable energy policy hypotheses. The results of these studies confirmed the potential for renewable energy to significantly contribute to the European energy mix, provided that appropriate incentives were set. If renewable energy was to be significantly promoted in the European Community – and it was, if the Green Paper was any indication –, then, specific incentives were needed that would enable renewable energy sources to meet their potential.

Regarding these incentives, the Commission stayed in line with the market-centred approach of the internal market framework. The introduction of renewable energy was considered to depend on the internalisation of external costs and on the correction of market failures then hindering the deployment of renewable energy technologies.

Though firmly articulated with concerns related to the good operation of the internal energy Market, environmental protection and particularly climate change mitigation was already a crucial element of European renewable energy policy, especially in the context of the negotiation and adoption of the Kyoto Protocol. It should also be noted that environmental protection is one of the criteria that can justify state aid in the European Community.

2.1.2.2. Renewable energy policy devices

The issue, then, was to create markets – or, rather, to nurture potentially competitive markets – the "natural" development of which was hindered by the failure to take external costs into account. Since renewable energy support was in place in some Member States before the European strategy was elaborated, the European Commission was able to list and map the variety of options for support. However, at this point, instrument choice did not seem to be the Commission's core concern. What mattered, according to the 1996 Green Paper, was that incentives frames provided sufficient transparency and stability to secure investments.

A relatively wide range of instruments can be used to help overcome obstacles to the formation of markets for RES-E, many of which bear similarities with environmental regulation instruments: credit systems, taxes, state aids, standards and norms, support to R&D... Renewable energy support schemes can thus be quite sophisticated and include several types of incentives that target different mechanisms.

RE development can, for instance, be achieved through renewable energy technologies improvement and cost reductions. To this end, two types of strategies can be combined: "technology push", which implies direct support to research and development in order to accelerate innovation, and "demand pull", which assumes that market deployment, for instance through investment subsidies, will trigger innovation and learning processes.

However, since increasing the share of electricity produced from renewable energy sources is both a means and an end, support can also be directly targeted at RES-E generation (subsidies per kWh of renewable electricity produced). Support to RES-E generation is expected to lead to increased installed capacity, thereby creating larger markets for renewable energy technologies.

Possibly because they can help fulfil both RES-E production and renewable energy technologies deployment objectives, generation subsidies would gradually become the dominant form of regulatory support for renewable energy in Europe.

> "Incentives that subsidize production are generally preferable to investment subsidies because they promote the desired outcome – electricity generation (Sauvin, 2001); they encourage market deployment while also promoting increases in efficiency (Neuhoff, 2004). However, policies must be tailored to particular technologies and stages of maturation, and investment subsidies can be helpful when a technology is still relatively expensive or when the technology is applied on a small scale." (Mitchell et al., 2011, p. 40-41)

However, they have rarely (if ever) been implemented on their own: in most countries, they are supplemented with diverse types of investment subsidies (renewable energy programmes, fiscal credits, local government subsidies…) and R&D support. In Germany and Denmark, the take-off of renewable energy was triggered by the combination of feed-in tariffs and investment subsidies or programmes, such as the German "1,000 solar roofs programme".

Nevertheless, while at the centre of most renewable energy support schemes, EU guidelines and academic research on the topic, generation support is rather idiosyncratic to renewable energy policy. Indeed, RES-E generation support instruments are designed to contribute to the different objectives that justify renewable energy market creation and development policies: they encourage investment in new capacity, increase in RES-E production, innovation and cost reductions in RET, and can even be set so as to internalise environmental and innovation external costs.

2.1.2.3 Supporting the generation of electricity from renewable energy sources

The rest of this chapter will thus focus on RES-E generation "subsidies", which narrows down the range of instruments to four main categories: feed-in tariffs, feed-in premiums, renewable energy quotas (RPS/TGCs) and bidding procedures. The two former are "price-based" instruments – they set a level of remuneration for RES-E but provide no certainty as to the quantity of RES-E it will bring – while the two later are "quantity-based" – they set a level of RES-E production to be achieved but provide no certainty as to the price that will be paid for to reach it.

Renewable energy quotas, called Tradable Green Certificates (TGCs) in Europe, set an amount of RES-E to be generated by allocating RES-E obligations to individual firms. Their logic is similar to that of carbon markets: each unit of renewable electricity generated gives right to a "tradable green certificates". The quantity of certificates available is determined by policy-makers, while their price is fixed on the market. To meet its obligations, a firm can either produce RES-E, purchase it, or purchase certificates from firms who have produced more RES-E that they had to. RES-E production thus supposedly occurs where it is less costly.

In bidding procedures, the government decides upon an overall objective, calls for bids, and then selects the projects that will benefit from support on the basis of a predetermined range of criteria.

Feed-in premiums work much like feed-in tariffs, except that they are connected to the fluctuations of prices on the electricity market. In such systems, RES-E producers receive a premium on top of the market price.

The four categories of instruments differ on the ways they articulate competition: feed-in tariffs tend to create isolated and protected markets that are not exposed to competition[91], while feed-in premiums connect RES-E markets to the electricity market. Bidding and quotas also articulate rather distinct forms of competition: quotas imply that all types of RES-E compete on the same level; bidding sets criteria along which competing investors will be ranked.

2.2. Orchestrating the promotion of electricity from renewable energy sources

2.2.1. Developing a common framework for energy policy: towards EU-wide harmonisation?

By the end of the 1990s, most Member States had adopted some form of renewable energy targets and/or incentives, though these were mainly recent policies. In many of them, the transposition of Directive 96/92/EC provided opportunity to introduce or modify renewable energy policy. Objectives for the development of renewable energy had been established at the EU level, but Member States was free to design their policy mix. As a result, renewable energy policy instruments varied widely from country to country.

Germany and Denmark, as mentioned earlier, used feed-in tariffs (though Denmark was planning to replace them with tradable quotas by the end of the 1990s). Spain introduced feed-in premiums in 1997; the Netherlands and Sweden were pioneers in voluntary green pricing schemes in 1996, while France and the UK had opted for calls for tenders: the Non-Fossil Fuel Obligation (NFFO) created in 1990 in the UK, Eole 2005 established in France in 1995.

In this context, the main purpose of the European Commission in making the promotion of renewable energy a policy priority was not to push Member States towards adopting renewable energy policies – most of them already had done so. Instead, it was to design a common framework that could ensure the coherence and stability of this wide variety of domestic policies, as well as, of course, their compatibility with an integrated European electricity market.

This purpose was made increasingly explicit as the elaboration of European renewable energy policy progressed. As the share of renewable energy was expected to increase

[91] Though they have been shown to foster competition among manufacturers, and in fact "shift competition from electricity price to equipment price" (Mitchell et al., 2011, p. 55).

(almost ineluctably, as political commitments had been taken, notably via the Kyoto Protocol), so were the potential distorting and negative effects of a lack of coordination between Member States policies. The priority was to agree on a set of common rules, as expressed in the Commission report on Harmonization requirements for the internal electricity market:

> "As already outlined in the White Paper on renewable energies, a clear need for common rules in this area can already be identified. The contemporaneous existence of different support schemes appears likely to result in distortions of trade and competition. The role of renewables in the EU will clearly increase in the coming years, given the Kyoto commitments. Thus, potential market distortions will accordingly increase. Whilst the trade and competition distorting effects of different renewable support schemes is rather limited at present, given the limited EU market share of electricity from renewable sources, this negative effect appears likely to significantly increase in the coming years. In this light, it is appropriate to move towards the definition of some common rules in this area as rapidly as practicable." (Commission of the European Communities, 1998, as quoted in Commission of the European Communities, 1999, p. 5)

A 1999 Commission Working Document on "Electricity from renewable energy sources and the internal electricity market" (Commission of the European Communities, 1999) provided the ground for discussions of these "common rules" by giving an overview of the different types of incentives for RES currently deployed in EU Member States and assessing their compatibility with EU rules and good functioning of the internal electricity market.[92]

The rationale for renewable energy support was not questioned: support was necessary to compensate for the (temporary) cost-disadvantages due to the non-internalisation of external costs of energy production; and it needed to be attractive enough to enable RES-E producers to enter the market, and stable enough not to deter investors.

2.2.2. The compatibility of incentives for renewable electricity generation with market integration

Before suggesting options for coordination and harmonisation of EU renewable energy policy, the working document reviewed existing support schemes. It distinguished between three categories of incentives to RES-E generation: "fixed feed-in tariffs", "quota (competition-based) systems" and "fixed premium schemes".

[92] "Subsequent to the White Paper on RES and the Harmonisation Report the Commission has analysed in detail the situation with regard to RES-E in the European Union. Existing studies and reports on the design and functioning of current support mechanisms as well as on barriers other than financial, such as administrative procedures and grid-system issues, were consulted. Furthermore, valuable information was received from Member States, on the basis of a questionnaire sent up by the Commission. Apart from the above investigations, discussions were held and/or comment received from many interested parties […]." (Commission of the European Communities, 1999, p. 45)

2.2.2.1. FITs: political instruments disconnected from the market

Though the Commission noted that "the highest levels of RES-generation increase have taken place in recent years in countries in which [a fixed feed-in tariff] operates" (Commission of the European Communities, 1999, p. 16), it made it quite clear that it did not favour feed-in tariffs as a long-term instrument for supporting renewable energy. Instead, it expressed a clear preference for competition-based systems. The main drawbacks of FITs, the Commission wrote, stemmed from their disconnection from the market. By guaranteeing a fixed price for a determined period, they created a space for investments isolated from markets risks. Potential investors were thus protected from both the fluctuations of electricity prices and the evolutions of renewable energy technologies markets.

> "In this manner, the actual price received by RES-E producers does not, necessarily, refer to any 'market price' for RES-E, nor necessarily take account of falling RES-E production costs due to technological improvements." (Commission of the European Communities, 1999, p. 12)

This disconnection from "market prices" made it difficult to articulate feed-in tariff-supported markets to others. Feed-in tariffs were not designed to directly incorporate the possibility of trade with neighbouring countries, or take into account cost reductions due to innovation, for instance.

Besides, since the level of tariffs had to be set by public authorities, the incorporation of any new piece of information not previously accounted for in the tariff would depend on government decisions. For the Commission, this was a major source of shortcomings. First, it clearly limited the security provided by FITs, which "only exists so long as prices are not modified frequently" (Commission of the European Communities, 1999, p. 15). It follows that, according to the Commission, FITs offered little flexibility and reactivity (since they would lose their main advantage if they modified too often), leading to low levels of static efficiency,[93] and hence to a failure to "produce price reductions for RES-electricity" (Commission of the European Communities, 1999, p. 16).

Not only were regulatory authorities considered unable to react quickly enough to price reductions resulting from efficiency gains, they were also viewed as exposed to political difficulties and pressure from producers when adapting tariffs so as to avoid excessive profit. A mechanism that did not depend on direct competition was also expected to provide little incentive for innovation, leading to low dynamic efficiency. Last, the document stressed that the nature of feed-in tariffs generated uncertainty as to their compatibility with the EU state-aid and internal market rules in the medium term.

For all of these reasons, though the Commission admitted that FITs could be an effective means to generate short-term increases in RES-E capacity and spark interest in these markets (which they *de facto* were doing in several countries), it did not envision them as a sustainable medium to long term option for RES-E support.

[93] In the Commission Working Document, static efficiency is defined as the "ability to ensure that electricity is generated and sold at minimum costs" and dynamic efficiency as the "ability to foster innovation, thus, again, driving down costs" (European Commission, 1999, p. 15).

2.2.2.2. Tradable green certificates: a device for the harmonisation of support to electricity from renewable energy sources

Initially, then the European Commission considered quota-based policy the best – and *a priori* least costly – option. The hypothetical lower total costs of TGC were not the only reason why the European Commission was inclined to favour them (Lauber and Schenner, 2011). In fact, the Commission's preference for quantity-based instruments probably stems from the fact that TGC were perceived as more "market-compatible" than FITs (Meyer, 2003, p. 668).[94]

TGCs also appeared as more suitable devices in the hypothesis of a harmonization of RES-E support frameworks at the EU level (Lauber and Schenner, 2011; Commission of the European Communities, 2004; Jacobsson et al., 2009). Besides, the similarities that TGCs shared with the ETS are likely to have played in their favour in EU-level discussions, even more so at a time when the EU, once a strong advocate of carbon taxation, was eventually and somewhat over-enthusiastically opting for a quota system for GHG emissions reduction (Branger et al., 2013).

The Commission was therefore rather straightforward in its preference for quota-systems which best fitted with both its clear focus on market integration and its affirmed faith in the role of market mechanisms to bring about environmental protection and technological change. It supported the progressive establishment of a harmonised community framework based on quantity-driven mechanisms (Lauber and Schenner, 2011). As Lauber and Schenner (2011) have shown, the Commission presented Tradable Green Certificates (TGC) systems as the most market-compatible solution, even though these had not been widely tested in Europe so far.[95]

TGCs were a theoretically elegant solution. They were compatible with the functioning of the internal market since they had been designed to be. On the other hand, the Commission considered FITs as an effectiv but *de facto* solution with less firm theoretical grounding, and that may not attract much attention if they had not already been in place in several countries.

As Lauber and Schenner noted,

> "[g]iven the strong belief in neoclassical economy, assumptions about the functionality of TGC were uncontested. Since no empirical experiences with TGC were available within Europe, theoretical assumptions could not be tested and went on faith." (Lauber and Schenner, 2011, p. 517)

Indeed, most of the existing literature on TGC was based either on theoretical analyses or on simulations of the expected impact of TGCs on RES-E development (Bergek and Jacobsson, 2010).

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[94] Many analysts dismissed this notion that TGCs were any more « market-based » than FITs, recalling that both instruments relied on the creation of artificial and regulated market conditions (Hvelplund, 2001 ; Meyer, 2003 ; Haas et al., 2011). "One (political) problem with the system is that a fixed price level does not conform to traditional market principles."

[95] A tradable quota system had been implemented in the US in the 1980s, where it is called « Renewable Portfolio System ». Interestingly, they were designed to replace avoided-cost tarification that the Reagan era deregulation had made seem not market-based enough (Lauber, 2004).

2.2.3. The contours of the "FIT v. TGC" debate

2.2.3.1. Prices and quantities in economic theory

By weighing FITs against TGCs, the European Commission re-opened the price v. quantity debate that is well-known in environmental regulation. (Interview 17; Ménanteau et al., 2003). The "price v. quantity" problem is a relatively old debate in environmental economics, and it is generally admitted that there is no absolute superiority of one type of policy over the other (Weitzman, 1974, p. 478). As Ménanteau et al. write,

> "As with environmental policies, under the dual hypothesis of perfect information on the cost of renewable energy projects and zero transaction costs, price-based an quantity-based schemes produce very similar results." (Ménanteau et al., 2003, p. 62)

However, economic analysis can provide insights as to which of the two options is best suited to a specific regulation issue. Weitzman (1974), attempting to correct the widespread misconception among economists that price instruments are always best, demonstrated that uncertainty was key to choose between price and quantity instruments (Lecuyer and Quirion, 2013).

The main difficulty in terms of general welfare is to identify the mot cost-efficient solution in situations of imperfect information. In the case of renewable energy development, in which neither the costs nor the benefits function are well-known, quantity-based instruments are often believed to allow for more control on total costs, since they set a cap:

> "Controlling the cost of a renewable energy promotion policy based on a feed-in tariffs is a classical difficulty associated with 'price-based' [...] rather than 'quantity-based' [...] environmental policies in situation of uncertainty over the costs and avoided damages function (Ménanteau & Finon, 2005)." (Finon, 2008, p. 18, author's translation)[96]

2.2.3.2. Prices and quantities in market regulation

TGCs also seem less dependent on regulatory choice and less liable to regulatory capture. One interviewee thus remarked that economists were inclined to expect TGCs to be more cost effective, since they "always think that an extremely competitive device based on quantities must logically lead to the least-cost result. Windfall profits seem unavoidable in a feed-in tariff system, since the regulator cannot be omniscient and know the tariff that correctly remunerates investment at every instant" (Interview 17).

The nature of quantity instruments, and especially TGCs, was expected to foster competition, and its proponents argued that it would thus direct subsidies towards the least costly (most mature) technological options and most favourable sites, and yield faster decreases in costs (Commission of the European Communities, 1999), whereas FITs could encourage suboptimal investment. Hence,

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[96] "Le contrôle du coût de la politique de promotion d'une énergie renouvelable basée sur le tarif d'achat est une difficulté classique des politiques d'environnement basées sur un 'instrument-prix' […] plutôt qu'un 'instrument-quantité' […] en situation d'incertitude sur la fonction de coûts et de dommages évités (Ménanteau & Finon, 2005)" (as cited in Finon, 2008, p. 18).

> "For some time, the RPS [Renewable Portfolio Standard, the equivalent of TGC in the US] was widely considered the least-cost approach to renewable energy development. The FIT was thought to be an expansive mechanism that did not stimulate sufficient competition within or across industry to bring costs down." (Lipp, 2007, p. 5492)

The matter was however hotly debated among economists (Interview 39). The momentary pre-eminence of quantity-based instruments owes more to European Commission's preferences, and the perceptions of these preferences by Member States,[97] than to conclusions drawn from economic controversies.

2.2.4. Harmonisation postponed

Not everyone agreed, though, and in the face of opposition, emanating from both the European Parliament and the Council, the attempt to design a harmonized community framework was given up, or rather postponed (Lauber and Schenner, 2011). The process launched by the 1996 Green paper resulted in Directive 2001/77/EC on the promotion of electricity from renewable sources and the internal electricity market, which set an a EU target for the share of RES-E as well as indicative targets for Member States (European Parliament and Council, 2001). Article 4 of the directive indicated that the objective of a harmonised framework had not been dropped, much to the contrary. RES-E policy was not mature enough yet to decide, but the issue was only postponed.

> "The Commission shall, not later than 27 October 2005, present a well-documented report on experience gained with the application and coexistence of the different mechanisms referred to in paragraph 1. The report shall assess the success, including cost-effectiveness, of the support systems referred to in paragraph 1 in promoting the consumption of electricity produced from renewable energy sources in conformity with the national indicative targets referred to in Article 3(2). This report shall, if necessary, be accompanied by a proposal for a Community framework with regard to support schemes for electricity produced from renewable energy sources." (European Parliament and Council, 2001, Article 4)

The perspective of a TGC-based harmonized EU framework had been a strong driver in the adoption of TGCs by Members States (especially Denmark, which changed from FITs to TGCs in order to align with European preferences). The fact that this perspective was now "rejected" into a distant future changed the picture. One of its consequences was to effectively disconnect the theoretical European internal electricity markets that the European Commission wanted to achieve from the more down-to-earth operation of creation of renewable electricity markets that was going on within Member States. Initially, the internal market model and the future renewable electricity markets in Member States could be superimposed since it was possible to envision that these markets would be develop according to the principles of the integrated European market, and with the purpose to help integrate it. However, by 2001, it was becoming clear that the two had diverged: the creation of RES-E markets in Member States had emancipated from the principles stated at the European level, and the integrated market progressively turned from a blueprint into an ideal.

[97] Denmark's shift towards TGCs, rapport Cochet

Section 3 – 2001-2008: Scale-one experimentation

In the aftermath of the 2001 Directive, renewable energy policy gained momentum throughout the EU. Support schemes in Member States multiplied, renewable energies emerged as actual sources of electricity generation, and the development of RES-E was structured as a topic for economics and policy research. In this process, feed-in tariffs evolved in several ways. As they were adopted in a growing number of countries and extensively studied, they grew more diversified and sophisticated in their designs; theories and mechanisms were devised to equip FITs to respond to market dynamics, in attempts to reinforce their links to markets and loosen their dependence on policy-making. FITs grew widely recognised as effective, thus gaining legitimacy as market-based instruments.

3.1. Evolutions in the promotion of electricity from renewable energy sources

3.1.1. Intensification, sophistication and standardisation

With the adoption of the 2001 directive, a new phase started for EU renewable energy policy. Targets (albeit indicative) had been fixed, and, in the process, available support instruments had been mapped out and previous and current experience assessed. The deployment of RES-E in EU countries had a legal framework, though a relatively loose one.

From then on, European renewable energy policy intensified in three main ways. First, as a direct result of the 2001 directive, a growing number of countries reinforced their renewable energy support schemes. EU-level consideration of the issue also increased, especially since the Commission had committed to regularly assess progress in RES-E development in Member States. Last, a growing body of literature, both grey and academic, focused on RES-E deployment and support, with particular attention paid to the compared virtues and flaws of available instruments.

These three sets of evolutions are, of course, not at all independent. They operated jointly, feeding each other in mutually reinforcing ways. Yet, they remain distinct in that they (at least partially) rely on different sets of practices and processes. Countries designed and used an ever more sophisticated array of policies to spur technological deployment through market creation; EU institutions, along with varied expertise-oriented organisms and institutions, monitored and assessed these policies and informed political discussions on the future of the EU RES-E framework; environmental and energy economists, along with public policy analysts, both documented and informed this ongoing process.

These simultaneous dynamics resulted in a gradual sophistication and standardisation of support mechanisms. Indeed, knowledge on RES-E support and policy was then being developed alongside a European-wide political process aiming at harmonising or at least coordinating domestic policies. Classifications were thus developed, and the characteristics and properties of various instruments were extensively studied and analysed.

As a result, the categories of instruments (that have emerged in the process) grew increasingly well defined, differentiated and stabilised. By being extracted from the peculiarities of national market and policy processes, RES-E incentives to an extent became transferable, standardised and comparable products. Lessons learned from one country could be used in or adapted for another, and so could improvements or refinements to an existing scheme.

3.1.2. Feed-in tariffs change status

3.1.2.1. The German Renewable Energy Bill: dynamic feed-in tariffs

Along this process, the European approach to the relationship between renewable energy policies, the markets they supported and the European-wide energy Market(s) evolved. In particular, feed-in tariffs changed status in the early 2000s. This change was brought about by a series of evolutions, among which the adoption of the 2000 *Eneuerbare Energien Gesetz* (EEG), or Renewable Energy Bill, in Germany.

Inspired from the local feed-in tariffs that existed for solar power in the country, the EEG introduced three major modifications to the instrument (Jacobsson and Lauber, 2006, p. 267). These modified the articulation of FITs to markets and innovation. First, tariffs were guaranteed for twenty years, thus increasing investors' security. The EEG also made tariff rates technology specific, with the clear purpose of promoting all types of renewable electricity sources, and not just wind power (which up to this point had been the main recipient of FITs). This was particularly relevant for solar power, still much more expensive than many renewable energy sources, as it made "solar cells […] an interesting investment option for the first time" (Jacobsson and Lauber, 2006, p. 267). Last, the EEG set annual decline rates for FITs for new installations. Intended to reflect the cost reductions triggered by the learning effects expected along market formation, these decline rates also were technology-specific. For photovoltaic power, the tariff was set to decline by about 5% every year.

The Social Democrats were motivated by industrial policy interests and by the will to create employment opportunities in pushing for the Feed-in Law reform (Jacobsson and Lauber, 2006; Mitchell et al., 2011), fearing that "the 1998 liberalisation of the energy market would lead to a long-term decline in employment in the energy sector and in the associated capital goods industry" (Jacobsson and Lauber, 2006, p. 267). However, in its wording, the EEG "repeated the Feed-in law's explicit commitments to take external costs into account" (Jacobsson and Lauber, 2006, p. 267).

Whatever the politics behind the elaboration of the EEG, the explanatory memorandum attached to it based its justification of the new FIT on market-oriented arguments similar to those developed at the EU level: the internalisation of external costs via the polluter-pays principle, the need to level competition in a context in which conventional energy sources remained heavily subsidised, and the will to "break the vicious circle of high unit costs and low production volumes" typical of RE technologies (Jacobsson and Lauber, 2006, p. 268; Federal Ministry for the Environment, 2000). FITs were presented as a device able to enhance electricity markets by taking account of environmental externalities, re-establishing fair competition between different energy sources, and correcting the barriers to investments that hindered technological innovation and deployment.[98]

With regards to these three goals, the EEG introduced what was by then the most sophisticated existing FIT scheme. It was not conceived as a government-fixed price to subsidise renewable energy so much as a dynamic device able to correct the "market imperfections" and barriers hindering the integration of renewable electricity. EEG FITs were designed to maximise investor's security – which is understood to guarantee the effectiveness of the instrument –, but also to incorporate information on technology costs, in a static (technology differentiation) as well as a dynamic (annual decline) manner. This was meant as a way to aim for efficiency by taking into account as much information on costs evolution as possible.

Aside from the tailoring of support to the specificities of each RE technology, the main innovation of the EEG was its attempt to make FIT less dependent on politics. The introduction of planned decline rates determined according to the innovation trajectories of renewable energy technologies was an attempt to make FITs able to "self-regulate". Stepped FITs were supposedly equipped to maintain autonomously in relation with market evolutions. Therefore, they no longer relied on arbitrary political adjustments (at least in theory), which was one of the key concern of the European commission with FITs.

3.1.2.2. PreussenElektra v. Schleswag: establishing the legitimacy of feed-in tariffs as market instruments

The EEG had impressive results in terms of renewable energy deployment, especially for wind and solar power (Jacobsson and Lauber, 2006). However, though the law clearly designed FITs as market-based instruments and attempted to make them more "market-compatible", DG Competition still raised doubts as to the EEG's compatibility with EU rules, which it did not lift until 2002 (Lauber and Jacobsson, 2006, p. 267). The legitimacy of Feed-in tariffs as market instruments, as opposed to state-aid, was yet to be fully established at the EU level.

Things began to shift in March 2001 with the European Court's ruling on PreussenElektra v. Schleswag (European Court of Justice, 2001). The core of the dispute was the compatibility of the purchase obligation of electricity from renewable energy sources created by the StrEG with the European Community Treaty. It was contested in two aspects on which the Court was asked to state: did it constitute State aid? And was it equivalent to a quantitative restriction on imports, and thus a distortion of trade

[98] Such justification was in line with the European Commission's approach, but also, like the StrEG, fits what Lauber refered to as "German Ordo-Liberalismus", which "stresses the need for the State to create a market framework for competition and to prevent monopolistic or oligopolistic power, and accordingly to prevent restrictions of market access, promote competition, and take measure against negative external effects" (Lauber, 2004, p. 1406).

between Member States incompatible with the principles of the Common Market (Jacobs, 2000; European Court of Justice , 2001).

On the bases of previous case law according to which State aid was to be interpreted in a restrictive manner as aid financed through State resource, the European Court of Justice rejected the German utility PreussenElektra's appeal to recognise the FIT defined by the StrEG as illegal State aid. It also stated that, though the StrEg purchase obligation is "capable, at least potentially, of hindering intra-Community trade", given that it aims at protecting the environment and that the particular features of the electricity market make it "difficult to determine [the origin of electricity] and in particular the source of energy from which it was produced", it was incompatible with Treaty rules (European Court of Justice, 2001, §17, 79). The European Court of Justice thereby sanctioned German feed-in tariffs as an acceptable means of support for RES-E development (Evrard, 2010; Hvelplund, 2001; Lauber, 2004).
The Court thus ruled that:

> "1. Statutory provisions of a Member State which, first, require private electricity supply undertakings to purchase electricity produced in their area of supply from renewable energy sources at minimum prices higher than the real economic value of that type of electricity, and, second, distribute the financial burden resulting from that obligation between those electricity supply undertakings and upstream private electricity network operators do not constitute State aid within the meaning of Article 92(1 of the EC Treaty (now, after amendment, Article 87(1) EC).
> 2. In the current state of Community law concerning the electricity market, such provisions are not incompatible with Article 30 of the EC Treaty (now, after amendment, Article 28 EC)." (European Court of Justice, 2001)

However, the European Commission maintained its doubts regarding feed-in tariffs. During the investigation of the PreussenElektra v. Schleswag case, The Commission was of the opinion that feed-in tariffs as designed in StrEG ought to be considered incompatible with the Treaty on the ground that they constituted State aid and could potentially hinder intra-Community trade. The Commission's priority remained the achievement of the internal electricity market as part of the Common Market, which in its view involved the harmonisation of RES-E support.[99]

3.1.2.3. FITs and TGCs as the building blocks of European markets for electricity from renewable energy sources

By the early 2000s, in addition to Germany, a growing number of European countries had adopted some form of FIT system among which Spain, France, Czech Republic, Greece, Portugal and Luxembourg (Commission of the European Communities, 2005).

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[99] It is noted in the Court decision that "the Commission took the view, in its Proposal for a Directive 2000/C 311 E/22 of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market (OJ 2000 C 311 E, p. 320), submitted on 10 May 2000, that the implementation in each Member State of a system of certificates of origin for electricity produced from renewable sources, capable of being the subject of mutual recognition, was essential in order to make trade in that type of electricity both reliable and possible in practice." The Commission's purpose was then to frame RES-E as a uniform good that would be tradable throughout a harmonised internal market without obstacles or differentiations.

Others adopted Tradable Green Certificates (TGCs) instead, with Denmark planning a switch from FITs to TGCs. FITs and TGCs turned out to be the two main devices used by EU Member States to promote RES-E, and the core features around which support schemes were articulated:

> "In the last ten years, the FIT and RPS have emerged as two key policies to promote the development of renewable energy for electricity generation. Several other policies are also in use but are generally peripheral to the FIT and RPS approaches." (Lipp, 2007, p. 5482).

By then, the main issue regarding European renewable energy policy was that of choosing between price and quantity instruments, and FITs and quotas (in the form of Tradable Green Certificates) quickly emerged as the two main alternatives. Bidding procedures had been relatively popular in the 1990s (e.g. the NFFO in the UK, Eole 2005 in France), but their results were overall deemed disappointing, and both governments and researchers gradually lost interest for them.

> "While quotas and tendering systems theoretically make optimum use of market forces, government tendering system in particular have often had a stop & go nature that has not been conducive to stable investment conditions." (Mitchell et al., 2011, p. 56)

These two instruments or rather categories of instruments (both can and do take various forms) had thus turned into the two main options for renewable energy support. RES-E policy became a matter of choosing one of the two as the core incentive, which could then be supplemented by additional instruments and measures (to direct investment, promote R&D, remove administrative barriers, etc…). FITs and TGCs were assembled as distinct, to an extent competing, options for support to RES-E markets formation through the interaction of domestic policies, the assessments of current and proposed incentives schemes by EU institutions or expertise and academic research in economics and public policy.

The multiplication of FIT systems in European countries and the European Court's March 2001 ruling made FIT a legitimate market instrument while a growing body of literature considered them as a research topic along with TGCs. Though some of this research focused on the political and policy-making aspects of RES-E support, a good deal of literature considered the topic from an economic and market creation perspective, confirming and reinforcing the change of status of feed-in tariffs brought about by their new legitimacy as market instruments.

3.2. The development of electricity from renewable energy sources as an area for research and experimentation

3.2.1. A field of research and expertise

In the aftermath of the elaboration of the Renewable Energy Directive, research on RES-E support and development intensified while existing support schemes gain maturity.

The literature on RES-E support was most of the time explicitly policy-relevant: a growing body of expertise and research developed to accompany Member States and EU policies. A "network of experimentation" (Callon, 2009) linking sites of research, business, policy-making, etc., was gradually constituted, allowing experience, practices and proposals to circulate quickly. Theoretical and practical concerns were interwoven as RES-E support took shape both as an area of policy-making and as an object of research.

A common perspective emerged from these interactions, and key notions and devices such as experience curves, learning-by-doing, or static and dynamic efficiencies became particularly influential in the way support instruments were conceived and designed. The articulation between stimulating innovation and internalising environmental costs remained at the core of the problematisation of RES-E support, as summed up in an influential paper by Ménanteau et al. (2003):

> "Whatever the system chosen, the role of the public authorities is quite specific: to stimulate technical progress and speed up the technological learning processes so that ultimately renewable energy technologies will be able to compete with conventional technology, once the environmental costs have been internalised." (Ménanteau et al, 2003, p. 799, emphasis added).

The literature on policies and instruments to support RES-E development thus thrived in the 2000s. It mainly explored the role of policy instruments in achieving the twin objectives of stimulating innovation and nurturing markets for renewable energy:

- an innovation-focused perspective, interested in the identification of drivers of technological change (e.g. Freeman, 1996; Foxon & Pearson, 2008; Jamasb, 2007; Midttun & Gautesen, 2007; Papineau, 2006; Schilling & Esmundo, 2009);
- an investment perspective, focusing on the conditions for investment risk reduction and market development (e.g. Awerbush, 2000; Couture & Gagnon, 2010; Dinica 2006; Lüthi & Wüstenhagen, 2012);
- a more theoretical economic perspective largely influenced by literature on environmental regulation, with which it shares an interest in the internalisation of external costs and in public goods, as well as a concern for climate change mitigation (e.g. Jaffe & Stavins, 1995; Lecuyer & Quirion, 2013; Ménanteau et al., 2003; Ringel, 2006; Schmalensee, 2012);
- an institutional and policy-making perspective, with a focus on environmental policies and on the institutional and political drivers of their adoption, design and implementation (e.g. Haas et al., 2004, 2007, 2011; Bergek & Jacobsson, 2010).[100]

These research streams already had a history largely independent from their newfound object of study, though not necessarily independent from one another. RES-E support had been addressed more or less directly from one or the other (sometimes from a combination) of these points of views during the 1990s, but papers on the topic had remained relatively isolated (e.g. Freeman, 1996; Wiser and Pickle, 1998; Loiter and

[100] In a similar view, Owen (2006) distinguishes three perspectives in research on the obstacles to the entry on renewable energy into the mainstream of the power sector: a research, innovation and deployment one (focused on the nature of innovation, on industry strategies and on learning processes), a market barriers approach (a view of the adoption of new technologies as a market process, focused on the framework within which investors and consumers make decision) and a market transformation perspective (interested in the practical dimensions of market building and influencing actors' attitude and decisions).

Norberg-Bohm, 1999; Midttun and Kamford, 1999; Norberg-Bohm, 1999; Awerbush, 2000; Jacobsson and Johnson, 2000).

Research on RES-E support was at no point independent from policy evolutions and debates, which it simultaneously informed and assessed. The community first structured around the debates over the respective merits and flaws of price and quantity instruments that gained importance when the European Commission considered options for harmonisation in the late 1990s (e.g. Hvelplund, 2001; Ménanteau et al., 2003; Lauber, 2004).

Academic debates thus appear closely related to the status of RE policy at the European and Member States level. In the case of the "FIT v. TGC" debate, despite actual theoretical divergences,[101] much of the disagreement resided on a "political basis" "around the role of government in supporting the RE sector" (Lipp, 2007, p. 5422; interview 39).

3.2.2. Theoretical and practical refinements

This close relationship between research and policy is clear in the evolution of the consideration of support to RES-E. In the 2000s, debates evolved from a relatively static approach to a more dynamic one: instead of identifying which types of instruments were the best (i.e. most effective, most efficient, least costly for society, safest for investors, etc…) to develop RES-E capacity and production, the aim was to design and pick the best suited incentives for each stage of technology and market development. Such preoccupations are the same as those the EEG reform addressed. Indeed, German renewable energy policy was to a large extent pioneering and influenced other European countries' policy choices. Having started to promote RES-E earlier than most, Germany also was first to face the consequences of its development; the issues Germany sought to address in 2000 thus gained importance as renewable energy progressed throughout the decade.

Three issues became central in discussions of RES-E support in the 2000s: the need to take into account the diversity of renewable energy technologies, increased attention to cost histories and innovation trajectories, and the adjustment of instruments to these innovation trajectories.

3.2.2.1. Taking the diversity of renewable energy technologies into account

First, the diversity of renewable energy technologies was increasingly taken into account. Support for RES-E mainly started with wind power, but by the mid-2000 renewable energies encompassed a much wider set of resources and technologies with very different cost profiles and "maturity".[102] As support was intended to help bring

[101] They are explored in more depth in the following section.
[102] The definition of "maturity" cannot be taken for granted; the constitution of this category is in fact quite complex, since it can incorporate technological, industrial, economic or political dimensions – most of which are not stabilised as such when considering emerging technologies,

renewable energy technologies out of the niches, views shifted from a one-size-fits-all policy towards instruments tailored to specific technologies (Midttun & Koefoed, 2003; Haas et al., 2004; Sanden and Azar, 2005).

> "A mix of policy instruments needs to be *tailored to the particular renewable energy sources and the specific national situation* to promote the evolution of the renewable energy sources from niche to mass-markets. This policy mix needs to evolve with the technology." (Haas et al., 2004, p. 838, emphasis added)

The first example this type of policy was set by the EEG and its technology-specific tariffs.

3.2.2.2. Following cost histories and innovation trajectories

A corollary of this technology-specific approach was the increased attention paid to cost histories and innovation trajectories. A large number of articles address the cost-reduction, innovation and learning dynamics of various renewable energy technologies and discuss the relevance of learning-curves and experience-curves approaches and of market support as opposed to R&D funding (e.g. Nemet, 2006; Papineau, 2006; Jamasb, 2007; Shum and Watanabe, 2008; Foxon and Pearson, 2008; Schilling and Esmundo, 2009). Considerations of the learning curves and respective levels of "maturity" of renewable energy technologies gradually merged with discussions on instruments designs and assessments. One of the main criteria used to compare categories of instruments was their ability to speed up technological progress at minimal social cost.

3.2.2.3. Tailoring support schemes to renewable energy sources and technologies

With technological progress being considered in a more dynamic way, instruments got to be judged according to their (transitory) ability to catalyze it in specific phases. As a result, instruments on both sides of traditional dichotomies (namely, technology push v. demand pull and, even more, quantity v. price) were considered not so much as competing but as complementary devices corresponding to different technologies at different stages in their evolution towards full market competitiveness. Increasingly, the subtlety of instrument design lay in the ability to implement the right instrument for the right technology at the right moment. FITs were usually considered best as the initial trigger, while quantity-based instruments were seen as best suited for technologies closer to maturity.

A growing number of articles discussed the compatibility of diverse support instruments to stages of technological development and encouraged a dynamic approach to policy mixes in which enforced instruments would evolve to accompany technological progress (e.g. Ménanteau et al., 2003; Midttun & Gautesen, 2007; Finon, 2008). A similar concern

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hence the inverted commas. This term would thus deserve detailed discussion. However, for the purpose of this paragraph, I take it to refer to a comparison of the dependence on support: wind power, for instance, has been around for longer than photovoltaic, and its costs have decreased enough to reach a level comparable with those of conventional electricity. Being closer to "competitiveness", it can be considered as needing less support than other, more expensive and less widespread technologies from which deeper cost reductions are still expected.

was expressed in the European SET Plan (Commission of European Communitites, 2007a), which states that:

> "The essence of the European Strategic Energy Technology Plan (SET-Plan) will be to match the most appropriate set of policy instruments to the needs of different technologies at different stages of the development and deployment cycle. The SET-Plan must therefore embrace all aspects of technological innovation, as well as the policy framework required to encourage business and the financial community to deliver and support the efficient and low-carbon technologies that will shape our common future." (Commission of the European Communities, 2006, p. 8)[103]

3.2.2.4. Adjusting support to market evolutions

This concern for the fit between support instruments and technology "maturity" translated into attempts to make instruments themselves better able to adjust to the market and technology evolutions they were meant to accompany. This resulted in a trend towards sophistication and refinement. For instance, technology bands were included into TGCs in order to make them able to differentiate between technologies and to avoid lock-in into the most competitive ones. FITs have been supplemented with decrease mechanisms meant to adjust incentives to cost reductions. The aim was to enable instruments to take into account an increasing amount of information, so that they could follow technology and market developments as closely as possible.

3.2.3. Documenting the experiment: surveys, assessment and formalisation

The momentum generated by the Renewable Energy Directive drove the constitution of a large collection of evaluations of renewable energy progress in EU Member States and of assessments of the increasing variety of support instruments and policies. A vast body of literature studied the designs and policy dynamics of renewable energy development. As the IPCC Special Reports on Renewable Energy Sources notes, "much of the literature describing and comparing these instruments, including their costs, is European and grey, stimulated largely by the need of EU countries to fulfil their Renewable Energy Directive requirements by 2020" (Mitchell et al., 2011, p. 45).

As planned by the Renewable Energy Directive, the European Commission regularly reports on renewable energy progress within the EU (Commission of the European Communities, 2004, 2005, 2008). To do so, besides Member States national reports, the

[103] Also: "The broad technology portfolio approach spreads risk and avoids locking-in to technologies that may not provide the best solution in the long run. The portfolio includes existing technologies that can be deployed immediately, technologies where incremental improvements are needed, technologies where breakthroughs are required, transition technologies and technologies which necessitate major changes to existing infrastructures and supply chains. All of these technologies face different challenges and barriers and are likely to be brought to commercialisation within different time horizons.
Creating the framework conditions and incentives for the development and take-up of energy technologies is a matter of public policy. A whole range of instruments is available at European and national level to help accelerate technology development (technology push) and the market introduction process (demand pull)." (European Commission, 2006)

Commission uses data, model outputs and assessment from expertise reports that it commissioned and funded. Not only do these reports directly contribute to the build-up of knowledge and expertise on renewable energy support schemes, they are also partly carried out by academics. The projects assessing RES-E support were thus funding economics and public policy research, and the evaluation of EU policy fed academic literature on RES-E market development.

In this light, the development of policy-supported RES-E markets in Europe in the 2000s can been seen as a process of live, scale-one experimentation: a variety of experiments are carried out and carefully documented and compared, innovations and hypotheses are tested both *in vitro* (using economic models) and *in vivo* (Callon & Muniesa, 2002; Muniesa & Callon, 2007; Callon, 2009), all in the purpose to improve the effectiveness and efficiency of incentives schemes and, in the long run, to develop sustainable renewable energy markets that are fully integrated to the European internal electricity market.

In this context, and even though EU-wide harmonisation remains an objective in the distant future, the coexistence of a wide diversity of support schemes in EU Member States is considered as an asset. Given the lack of previous experience in supporting RES-E and the "immaturity" of existing support schemes and policies, it provides an opportunity to gather an impressive amount of know-how in the field, and holds the potential to devise "better" solutions in the process. This is pretty much what the European Commission argued in the annex to its 2005 Communication on the support for electricity from renewable energy sources:

> "While gaining significant experience in the EU with renewables support schemes, competing national schemes could be seen as healthy at least over a transitional period. Competition among schemes should lead to a greater variety of solutions and also to benefits: for example, a TGC system gains from the existence of a feed-in tariff scheme, as the costs of less efficient technologies fall due to the technological learning, which in turn leads to lower transfer costs for consumers. Systems are already leaving behind the 'great divide' between price- and quantity-based approaches. This might be the way forward, with specific instruments aimed at specific policy goals and the overall support framework intelligently linked to other electricity market regulation." (Commission of the European Communities, 2005, p. 16)

3.2.4. Accounting for the success of feed-in tariffs

By the mid-2000s, the trend was clearly in favour of FITs. Against expectations perhaps, most evaluations seemed to conclude that they were overall more effective and less costly than TGCs. The main reason for this was their success in triggering investment in new installed capacities: in countries with FITs, RE capacities increased faster than it did in countries with TGCs.

3.2.4.1. Making investment in "non-mature" technologies attractive

Combined with RES-E generation targets, the focus on learning processes had made the increase in installed capacity critical in both a static (achieving current objectives) and dynamic (setting RES-E on the path to competitiveness) perspective. Deploying renewable energy technologies and RES-E generation capacity requires investments in renewable energy projects. Considered at a micro-level, then, what RES-E support really does is make such investments in RES-E installed capacity attractive by enhancing their potential profitability and reducing the risks attached to them. That investment security was a key condition for market uptake became particularly clear when stock of the performance of various instruments was taken, in the mid-2000s. Contrary to expectations, FITs have indeed performed much better than alternative schemes in terms of growth in installed capacity, as analysts have noted:

> "Several recent policy assessments show, however, that the UK [Renewable energy obligation] as well as other European quotas systems produce renewable electricity at a higher cost than the FIT (EC, 2005)." (Lipp, 2007, p. 5492)
>
> "[FITs] have consistently delivered more renewable energy supply more effectively, and at lower cost, than alternative policy mechanisms." (Couture and Gagnon, 2010, p. 955).

3.2.4.2. Feed-in tariffs and investment security

The security that FITs provided to investors and project developers was put forward as the main explanation for their effectiveness. Indeed, when it comes to reducing investment risk, few mechanisms fare better than FITs, which guarantee long-term visibility over income. As Couture and Gagnon explain:

> "by basing the payment levels on the costs required to develop renewable energy projects, and guaranteeing the payment levels for the lifetime of the technology, FITs can significantly reduce the risk of investing in renewable energy technologies and thus create the conditions to rapid market growth (Lipp, 2007; International Energy Agency, 2008). This structure provides a high degree of security over future cash flows and enables investors to be remunerated according to the actual costs of renewable energy project development. This security is particularly valuable for financing capital-intensive projects with high upfront costs and a high ration of fixed to variable costs (Guillet and Midden, 2009; see also Harper et al., 2007)." (Couture & Gagnon, 2010, p. 956)

In particular, quantity-based mechanisms cannot provide such certainty over return on investments. As a result, the payment of a risk premium (i.e., higher remuneration for the same level of production) is usually required, which explains that TGCs and bidding systems have turned out more costly than FIT schemes on the whole.

> "In theory, this difference should not exist as bidding prices that are set at the same level as feed-in tariffs should logically give rise to comparable capacities being installed. The discrepancy can be explained by the higher certainty of current feed-in tariff schemes and the strong incentive effect of guaranteed prices." (Sims et al., 2007, as cited in Mitchell et al., 2011)

Finon (2008, p. 15, author's translation) mentions the "stable signal quality that is specific to feed-in tariffs and that is favourable to investments in capitalistic equipments, as opposed to other schemes such as tradable certificate obligations, which do not offer reliable revenue". The European Commission eventually reached the same conclusion, noting in its 2011 review of European and national financing of renewable energy that

> "reviewing the relationship between project risk and instrument choice, the empirical evidence suggests that the more reliable revenue stream provided by feed-in tariffs is generally more effective in driving renewable energy growth, particularly for a broad range of technologies. Quota obligation and tradable green certificates often suffer from

> revenue volatility and require payment of a risk premium, which appear to make them both less effective and efficient." (European Commission, 2011c, p. 6)

3.2.4.3. Feed-in tariffs and diversity

A related characteristic of FITs is that they enable a very diverse range of renewable energy technologies and projects to co-exist and share support. FITs are indeed particularly reassuring for investors because they do not expose them to competition. Whereas TGCs support renewable energy in a generic manner[104] and imply that all are exposed to the same market conditions, FITs can be easily tailored to take into account the specificities of technologies and investment models. Their support is not limited to the most mature technologies and the areas with the highest renewable energy potentials, and, as the SRREN note, they "have encouraged both technological and geographical diversity, and have been found to be more suitable for promoting projects of varying size" (Mitchell et al., 2011, p. 55).

Though this can be considered a flaw in a pure "cost-efficiency" perspective, advocates of FITs have often stressed their flexibility and their ability to generate diversity as key assets (Hvelplund, 2001; Lipp, 2007; Couture and Gagnon, 2010). On top of making it easier to promote renewable energy technologies in their diversity, the high investment security that FITs provide indeed allows non-traditional actors to enter the market: they enable "a greater number of investors to participate, including homeowners, landowners, farmers, municipalities, and small business owners, while helping to stimulate rapid renewable energy deployment in a wide variety of different technological classes" (Couture and Gagnon, 2010, p. 955).

This has led some analysts to argue that FITs are well-suited to the characteristics of RES-E, because they are effective in "favouring early and rapid growth" of technologies still relatively far from market competitiveness (Lauber, 2004, p. 1411-1412) and with high upfront costs, while permitting their development at diverse scales and by various actors (Hvelplund, 2001; Couture and Gagnon, 2010).

According to Hvelplund (2001), the better conformity of price-based instruments to the characteristics of RET is reinforced by the way they articulate competition. FITs, he argues, do not suppress competition but shift it from the electricity to the equipment market, which is after all appropriate for a sector with high upfront costs but low maintenance costs, and where most of the value lies in the equipment:

> "In the present situation of technological change, the 'Political quotas/certificate price market' system ends up introducing competition on a dwindling market and abolishing competition on an expanding market." (Hvelplund, 2001, p. 19)

The 2000s constituted a phase of scale-one experimentation characterised by the emergence of actual RES-E markets which became players in the game and had to be taken into account. Policy-driven RES-E markets developed throughout Europe and their progress was closely monitored and assessed by the European Commission and simultaneously fed research and theorisation of the topic. Feed-in tariffs came out of

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[104] At least in their most basic forms. More sophisticated models with "technology bands" have been developed in order to avoid lock-in the most mature technologies.

this process transformed: there was no longer a “one-size-fits-all” tariff but, instead, a wide variety of FITs designed to be adjusted to specific technologies and level of maturity. The divide between price and quantity-based instruments shrank, and the European Commission adopted a more pragmatic stance and to consider the proliferation of support instruments a sign of the gradual perfection of renewable energy policy. The purpose was no longer to ensure that all renewable energy policies converged in the achievement of a Common Market but to successfully develop diverse but functional emerging markets that would later be able to converge through exchange of best practices.

Section 4 – 2008 onward: Turbulence and reforms

Experimentation kept going after 2008, and to an extent even intensified. However, it took place in a more turbulent context. The RES-E markets that had emerged started to overflow and their unintended effects had to be attended to quickly. As reforms became necessary, some features of feed-in tariffs were reconsidered. The mechanisms supposed to enable FITs to stay in line with markets evolutions proved unsufficient, and some degree of political steering was required. Reform turned out to be a crucial part of the functioning of photovoltaic support, since photovoltaic markets were changing so fast and unpredictably. The key issue, partly unresolved as of today, was then to incorporate reform into support while maintaining markets that were both functional and fair.

4.1. Making sense of the evolution of electricity from renewable energy sources in Europe

4.1.1. The Climate-Energy Package

By the mid-2000s, RES-E support schemes implemented in the wake of the 2001 directive started to have effects. The EU then began working on a second energy package, an objective of which would be to further increase the use of renewable energy sources (Commission of the European Communities, 2006, 2007a, 2007b, 2007c).

The “Energy Package” proposed by the Commission on January 10, 2007 comprised three documents relevant to RES-E support: a communication entitled “An Energy Policy for Europe”, which outlined the ambition to define a framework for a high energy efficiency and low carbon emission economy and insisted on the importance of defining a long term vision for energy technologies (Commission of the European Communities, 2007c); the launch of the “Strategic Energy Technologies” (SET) Plan, which focused on innovation in energy technologies, particularly renewable energy technologies, and justified RES-E support instruments as a way to drive innovation (Commission of the European Communities, 2007a); and a “Roadmap for renewable energy sources” stressing the risk not to meet the 1997 RE development objectives and proposing a target of 20% RES in EU energy consumption by 2020 (Commission of the European Communities, 2007b).

On the same day, the Commission also published its communication “Limiting global climate change to 2 degrees Celsius: the way ahead for 2020 and beyond” (Commission of the European Communities, 2007d). This was only a first step in the coupling of climate and energy issues at the European level, which was later confirmed by the adoption of the Energy-Climate Package in 2008.

As this evolution indicates, policy priorities had shifted: climate change and security of supply were gaining importance over the completion of a liberalised internal electricity market that “proved rather intractable” (Lauber and Schenner, 2011, p. 523). The promotion of renewable energy became a more important objective than the liberalisation of the electricity market – even though the Commission kept pushing for EU-wide harmonisation in the longer term (Lauber and Schenner, 2011).

An outcome of this process was Directive 28/2009/EC on the promotion of the use of energy from renewable sources, which set binding national targets for energy produced from RES on the basis of the overall EU target (20% energy from RES in total energy consumption by 2020) (European Parliament and Council, 2009). This confirmation and continuation of the EU’s commitment to renewable energy promotion took place in a context of gradual sophistication and hybridisation of RE support systems. In fact, while expertise and research on the topic thrived, assessing experience and sorting out knowledge on the various existing instruments, the picture was growing increasingly intricate.

4.1.2. A healthy convergence?

After several years in operation, RE support schemes had gained relative maturity. The simultaneous experimentation of a variety of designs for RE support in different countries combined with the proliferation of research and assessments to allow for an exchange of practices between countries. The objective to maximise both the effectiveness and the cost-efficiency of instruments (which are in fact rather difficult to combine in the case of RE support) resulted in the invention of hybrid systems that attempted to combine the advantages of price- and quantity-based instruments, blurring the line between two theoretically well-established categories.

In a 2008 evaluation of the support of electricity from renewable sources, which accompanied the proposal for a directive on the promotion of the use of energy from renewable energy sources, the European Commission greeted this evolution with unabashed optimism (Commission of the European Communities, 2008).

> “Several Member States have reformed their support schemes to differentiate between technologies to encourage technological diversity. Although the basic nature of the existing support schemes in place varies between Member States as does the level of support to different technologies, *there are clear signs that a degree of convergence of important properties of the policy measures is emerging*. Support schemes have also been *reformed to introduce market signals* through the incorporation of market prices using premiums rather than feed-in tariffs, thus *improving the compatibility of the support with internal market rules* and adjustments of tariffs to reflect decreasing production costs. This results in both an *improvement of the existing measures and a gradual increase in the effectiveness and efficiency of support to promote renewable electricity*.
>
> As a result of incorporating elements of different schemes, *the clear distinction between the different support schemes are fading and their known problems are diminishing*: technology specific obligations or green certificates can ensure that such regimes no longer develop only the current cheapest technology; greater use of feed in premiums can

> ensure that producers have stronger incentives to minimise costs. Thus in general, it is clear that Member States are aware of and learning from the failing of their own support schemes and the best practices in other Member States" (Commission of the European Communities, 2008, p. 14, emphasis added).[105]

This line was maintained in the more recent review of Member States renewable energy policies that the Commission issued in 2011:

> "The use of multiple instruments or the adaptation of instruments also reflects Member States' efforts to improve the efficacy of the instruments in a gradual manner without causing too much disruption to the market. Changes in recent years have seen a blurring of the traditional dichotomy of tradable certificate (setting quantity not price) and feed in tariffs (setting price not quantity). [...] In addition, Member States make smaller annual changes – to the quotas, to the tariff or premium rates, to the lifetime of the support, and to aspects of eligibility. All of these changes improve the efficiency of the instruments But more needs to be done." (European Commission, 2011c, p. 7, emphasis added)

However, the refinement and hybridisation of instruments through the exchange of "best practices" did not happen as smoothly as Commission reviews suggest. In fact, it took place in a relatively disorganised way and was mostly driven by the need to correct flaws and failings in existing support schemes before their political and economic cost grew too important.

4.2. Sea-changes in the appreciation of feed-in tariffs

4.2.1. Successes and shortfalls of feed-in tariffs for PV-generated electricity

By 2008, FITs were the most widespread RES-E policy instrument in EU member states. Their effectiveness in triggering rapid growth in RE capacity made no doubt, and the German EEG was widely hailed as a success and held as an example (Interview 39; Mitchell et al., 2011, p. 52). Several research papers stress that "evidence suggests, albeit tentatively, that feed-in tariffs (FITs) are more effective than alternative support schemes in promoting renewable energy technologies" (Lesser and Su, 2008, abstract) or, in similar terms, that "recent experience from around the world suggests that feed-in tariffs (FITs) are the most effective policy to encourage the rapid and sustained deployment of renewable energy" (Couture and Gagnon, 2010). Even the European Commission then admitted their good performance:

> "[This report] finds that, as in 2005, well-adapted feed in tariff regimes are generally the most efficient and effective support schemes for promoting renewable energy." (Commission of the European Communities, 2008, p. 3)

However, critiques of renewable energy support schemes began to be voiced, highlighting some of the problems that had emerged from their implementation in several countries. They stressed that the development of RES-E could not be reduced to growth in installed capacity. This led to contesting the adequacy of FITs in some cases: the focus on economic instruments and installed capacity, as if RES could be considered

[105] These conclusions are drawn from the OPTRES report, the executive summary of which expresses the same ideas using similar wording (OPTRES, 2007, p.2).

only in terms of their tradable electricity output, might draw attention away from other crucial aspects.

4.2.1.1. The hegemony of economic instruments reconsidered

Researchers began to draw attention to other elements of Renewable energy support than economic instruments, stressing the fact that the focus on one single type of instruments had led to overlook the effects and importance of other policies which in some cases had been crucial. In particular, in a 2008 paper, Dinica warned about the dominant "narrow conceptualization of policy referring mostly to direct instruments for economic feasibility" which "often led to unsatisfactory explanation of diffusion results" (Dinica, 2008, abstract). The focus on a few instruments has obscured the complexity of RE support policy, she argues, since it often has led to the conclusion that "the described instruments led to the observed diffusion results, as if there was little to nothing in between" (Dinica, 2008, p. 3563).

Taking the example of wind power development in Spain, she shows that it owed much more to a political and institutional context that encouraged and facilitated Public-private partnerships (PPPs) for wind power projects than to FITs. Indeed, though FITs were instituted in Spain in 1994, they provided a rather insecure framework for investments until 2004, and would therefore not have constituted much of an incentive for risk-adverse Spanish economic actors. PPPs, however, created the trust in wind power projects that was necessary to draw banks, developers and industry in and to generate a sustained growth in wind installations.

Yet, Dinica regrets that the trope towards economic instruments that dominates in the academic and policy arena has led many to attribute the successful development of wind power in Spain to feed-in tariffs without thorough consideration of the evolution of policies and of diffusion patterns. The fact that feed-in tariffs have been a successful trigger for renewable energy development in Denmark or Germany should not bring to the conclusion that they *always* are the main driver for renewable energy development.

By shifting attention from debates on the design of a few economic instruments considered as the main elements of renewable energy policy, Dinica's paper brought the complexity of policy and market arrangements to the foreground. Renewable energy development cannot be reduced to the details of designing instruments that would be immediately transferable from country to country without paying attention to specific political and economic contexts that largely shape the way market players approach investment risks and innovation.

Such a view may not have become dominant, but it nonetheless altered the debate by drawing attention to the fact that there was more to renewable energy policy than instrument design. It was also a sign that the focus of researchers and policy-makers was shifting from an abstract, uniform conception of instruments to one in which RE policy instruments had to be adjusted to a given market for a given technology in a given country at a given time.

4.2.1.2. The adequacy of feed-in tariffs for PV-generated electricity challenged

Indeed, renewable energy support instruments were no longer considered in general terms: the issue was to determine their suitability for supporting the development of specific renewable energy technologies. The adequacy of FITs as the main support instrument was particularly debated in the case of photovoltaics. FITs had initially been developed to support wind power generation, and their suitability to other renewable energy sources with very different characteristics could not be taken for granted.

A set of critiques was based on the innovation studies literature and questioned the relevance for photovoltaics of the "learning-by-doing" approach underlying most RES-E support policy. For instance, Finon (2008) argued that photovoltaic technologies were not mature enough yet to justify their support through generation subsidies. Schilling and Esmundo (2009) took a similar stance by choosing to focus on "learning by searching" rather than "learning by doing" and showing that the funds spent on photovoltaic support were out of proportion with their impact in terms of cost reduction and efficiency gain.

Many analysts have stressed that, even though the learning curve model seems to apply rather well to photovoltaic panels manufacturing[106] (van der Zwaan and Rabl, 2004, p. 7), in which cost evolution roughly follows Moore's law (Interview 6), the relevance of learning-by-doing to evolving and emerging technologies such as RET remains uncertain (Jamasb, 2007). Schmalensee (2012, p. 48) points out that learning "only provides an economic justification for subsidies if there are spillovers from one producer to others". In the case of photovoltaics, he writes, such spillovers have not been demonstrated, and neither has it been shown that

> "costs are more effectively reduced by subsidizing deployment of today's expensive technologies than by directly supporting research and development aimed at finding lower costs alternatives or offering prices tied to generation costs" (Schmalensee, 2012, p. 48).

In fact, as van der Zwaan and Rabl (2004, p. 9) point out,

> "[The learning curve] provides little to no explanatory value. This property of the learning curve methodology implies that it remains difficult to assess how precisely one needs to go about promoting PV or stimulating cost reduction."

Other critics altogether dismissed FITs as a means to support the deployment of photovoltaics. For instance, Frondel et al. (2008, 2010) questioned the apparent consensus over the "German renewable energy success". They argued that in spite of their effectiveness in promoting photovoltaic power, German feed-in tariffs had failed to bring about any of the benefits that could be expected from the deployment of photovoltaics. In particular, according to them, feed-in tariffs have not proven able to help the emergence of domestic equipment industries and to create jobs. The costs of feed-in tariffs for PV-generated electricity, they write, have been disproportionate, and

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106 Watanabe and Shum (2008) have shown that experience curve effects driven by production learning and R&D could account for the cost evolution of photovoltaic cells and modules, but that the economics of system integration and deployment in the downstream value chain were driven by more refined inter-project learning.

photovoltaic power benefited from a preferential treatment that failed to contribute significantly to climate protection and/or job creation. This critique gained ground as the Chinese photovoltaic panels industry developed and "flooded" the European market, and as the financial crisis made the costs of renewable energy policy a critical matter.

4.2.1.3. The impact of the financial crisis

These debates over the adequacy of support to photovoltaic power occurred at a time when FITs schemes in European countries started to raise concerns. In 2008, Spain's photovoltaic support system experienced a burn-out. Following a blistering growth that had propelled Spain in the top-3 countries in terms of photovoltaic capacity but also weighed heavily on the public budget; the 1758/2008 Royal Decree retroactively lowered tariffs and refined their design to curtail development.

Come 2010, most countries with feed-in tariffs had problems with their renewable support schemes, especially where photovoltaic electricity was concerned. The impact of the financial crisis converged with global photovoltaic market evolutions to disrupt most support schemes.

First, in the context of the financial crisis, incentives that were designed specifically to reduce investment risk (which is what renewable energt support instruments were, especially FITs that effectively suppress risk) turned renewable energy projects into particularly attractive investment options. This was especially true for photovoltaic projects for two main reasons: they are relatively easy to carry out and, between 2008 and 2009, the cost of photovoltaic modules decreased dramatically (Bazilian et al., 2013), leading to discrepancies between project costs and FIT remuneration levels. This was a recipe for success and disaster at the same time. Success was indeed achieved in terms of installed capacity development, but its unexpected level translated into unexpected costs.

Now, another consequence of financial and subsequent economic crisis was that increased attention was paid to the cost of renewable energy policy as well as to their economic, social and industrial benefits (Interview 17). Renewable energy support grew increasingly expensive just when controlling and limiting spending was becoming a major concern of European governments. Success triggered instability in support (Ecofys, 2013, p. 32).

4.2.2. Reforming instruments

4.2.2.1. *Ad-hoc* adjusments and bricolage

When considering the evolution of RES-E support schemes towards sophistication and hybridisation, it is thus important to keep in mind that it took place in a context of relative turmoil: it was indeed mainly driven by the need for governments to quickly devise solutions to the new problems brought along by RES-E development. One interviewee related in details this transition from an *a priori* simple problem with a limited range of simple and elegant solutions to a messy process of bricolage and experimenting.

> "One could say that, in fact, the variety of renewable energy support systems is limited, yet experience has actually shown that it diversified all the same. […] In theory, if you are an economist, things are extremely simple; there are only two types of devices: quantity or price. If you know the quantity, you don't know the price, and if you know the price, you don't know the quantity. So at first everybody was saying: 'either we use feed-in tariffs, or we use tradable certificates or tendering'. There were only three objects. Now, I'm looking beyond photovoltaics only to explain why learning was actually not so simple. For that matter, in the early years of renewable energy support, before 2008, countries indeed hesitated between the two and a very limited number of countries converted. By and large, the sense of history was a bit paradoxical for an economist. That is, experimentally we observe that in several sectors, for about the same installed capacity, all other things equal and after correcting for climate etc., it tended to be a little more expensive in countries with tradable certificates than it was in countries with feed-in tariffs. This was upsetting for an economist who always believes that an extremely competitive quantity-based instrument must logically lead to a less costly result. Windfall profits seem unavoidable within a feed-in tariff system since the regulator cannot be omniscient and know at every instant the rate that correctly remunerates investments. […]
>
> When the photovoltaic crisis started, we started trying to refine all the systems beyond this overly simple opposition. And that's where I think it was difficult, because we had to invent things that could make the incompatible compatible along the way. […] So improvements were made on the tradable quota systems, one may say, but that at the same time falsified it. On the tariff side, we said: 'we can see that it is drifting away', so experiments were tried like in Spain and Germany, either hybrid systems or systems that turned the logic upside-down. In the end, the difficulty was that we thought it was an extremely simple economic theory problem with an extremely limited number of solutions, and then we kept on refining it, trying to turn a few screw to get something that would combine too many objectives: we want to promote all technologies, we don't want the tax to increase too much, we want a risk-structure that is acceptable for investors otherwise they will legitimately ask for better capital remuneration… There was this whole series of compromises, so we kept on patching innovations together. […]
>
> To put it shortly, it took place in a great mess because we were in the thick of several problems: on the one hand, in some countries it was too expensive, and on the other hand, in some sectors we had trouble obtaining as smooth a development as many governments wanted. And in the end, we did tamper a lot with it… So people went on missions in neighbouring countries to see if Peter's solution could be transposed to Paul, if necessary with a few modifications." (Interview 17)

4.2.2.2. Feed-in tariffs for PV-generated electricity in crisis

Thus, the sophistication of support schemes was not so much the sign of a healthy convergence through experimentation and exchange of best practices as the result of series of hasty and ad-hoc reforms made necessary by the difficulty to adjust instruments to changing objectives and constraints. The most brutally affected schemes were those that included feed-in tariffs for PV-generated electricity. Virtually all of those in Europe underwent rather dramatic reforms between 2008 and today, and few have fully recovered.

As mentioned above, Spain was the first country to drastically reduce photovoltaic support after a brisk increase in installed capacity that came to weigh too heavily on public finance. In Germany, where objectives are overshot on a regular basis, a revision of the EEG in 2009 introduced a system of dynamic FIT decrease based on the rate of development – the decrease rate had to be adjusted every year since then (Hoppmann et al., 2014). In the Czech Republic, a moratorium on FITs was decided in 2010, and a decrease in FIT rates came into effect the following year.[107] In the UK, where FITs were introduced in 2010, those for photovoltaic power were cut and reviewed in late 2011. In France, as this thesis extensively studies, the FIT system was reformed several times in 2010 with so little effect that a moratorium and thorough revision was eventually decided in December 2010.

These reforms may have contributed to improvements in the design and efficiency of support schemes, as Ecofys suggests:

> "Apart from those countries which have put their support for new installations on hold, most Member States are continuously refining and [sic] their support systems to improve their effectiveness and efficiency." (Ecofys, 2013, p. 102)

However, their relative brutality also generated unpredictability in a context in which reliability and investor confidence are crucial. The 2013 Renewable Energy Progress by Ecofys, commissioned by the European Commission, stresses the joint influence of the financial crisis and the swift reduction of photovoltaic module costs in this matter, noting that

> "Overall, we can observe that the recent economic crisis has affected the reliability of RES support in a number of member states." (Ecofys, 2013, p. 100)

and that

> "A number of countries made abrupt changes to their RES-E support schemes in 2010 and 2011 to keep up with the rapid price development on the PV market (e.g. Spain, Czech Republic, the UK, Latvia, Portugal), but these changes undermined the confidence of the investors which is a serious threat to the success of RES policies in the future." (Ecofys, 2013, p. 12)

In recent years, reforming FIT schemes while maintaining some degree of stability and predictability in support has thus proved a challenge. The difficulties faced by European governments confirmed that fine-tuning of incentives could be a challenge. They fed a process of experimentation and bricolage that aimed a improving and in some cases reorienting instruments.

4.3. The challenges of FIT design: setting and keeping the price right

The consequences of the emergence of actual photovoltaic markets that required monitoring and steering, combined to unexpected events such as the financial crisis or the take-off of photovoltaic modules production in China, converged in making reform appear necessary. Feed-in tariffs had to be adjusted to suit redefined priorities and adapted to a changing context. In this process, the basic principles of RES-E support instruments were not as debated as they had been, especially since the increased

[107] "The Czech Republic experienced the sharpest increase in PV electricity generation, from 89 GWh in 2009 to 616 GWh in 2010. This increase is the main reason for the current instability in the Czech support scheme. […] A number of countries opted for changes in their support level adjustment mechanisms in 2010 and 2011 to keep up with the rapid price developments on the PV market." (Ecofys, 2013, p. 32)

hybridisation of price and quantity instrument had made such discussion less relevant. Instead, increased attention was paid to details in their designs. This trend is not specific to FITs but affects renewable energy policy more generally. As Lüthi and Wüstenhagen wrote,

> "one way of summarizing the debate is that for many renewable energy policies, the devil is actually in the details (Ringel, 2006), and it is a fine-tuned set of ingredients of a country policy mix rather than any archetype of a 'price-driven' or 'quantity-driven' policy instrument that results in efficient and effective deployment of renewables (Dinica, 2006; Ménanteau et al., 2003)" (Lüthi and Wüstenhagen, 2012, p. 1002).

For instance, the high investor security that is considered a key aspect of the success of FITs, is not intrinsic to FIT schemes; it mainly depends on careful design of support schemes whatever the means of support privileged (Dinica, 2006; Lipp, 2007).

By the end of the 2000s, the main problem with FIT-supported photovoltaic markets was that they were growing too fast. The success of feed-in tariffs in increasing installed capacity led to overflows that turned out difficult to control. As a result, the key issue in reforming feed-in tariffs was the calibration of incentives: they needed to be strong enough to drive investments, but not so strong as to over-stimulate the market. There are two aspects to the calibration of feed-in tariffs. First, policy-makers have to determine the initial feed-in rate; this first step is far from straightforward, which was used as a justification for the European Commission preference for quantity-based instruments in the 1990s. The evolutions of photovoltaic markets over the 2000s revealed an additional challenge in calibrating feed-in tariffs: not only must prices be set at the right level; they must also be kept at the right level. In other words, mechanisms have to be devised to enable feed-in tariffs to adjust to dynamic market conditions without damaging the reliability of support.

4.3.1. What is a right price?

The first difficulty in FIT design is to set the price right. FIT schemes require that policymakers "substitute their judgement for that of markets in the selection of long-term, technological 'winners and losers'" and "define administratively FITs attributes, specifically payment amounts for individual technologies […], payment structures (e.g. fixed or declining), and payment duration", all of which "can require significant 'guesswork' […] as to future market conditions and rates of technological improvements" (Lesser and Su, 2008, p. 982). Though these difficulties were identified and studied well before the late 2000s, determining the best-suited method and obtaining reliable information to decide upon the appropriate price level remains a major challenge for policymakers. To an extent, recent developments on the photovoltaic markets have even made it more complicated.

4.3.1.1. Theoretical approaches to the calibration of feed-in tariffs

Ménanteau et al. (2003, p. 56-57) remark that, as "it is impossible to refer to an optimum level of renewable energy production", "one is forced to adopt a strict cost/efficiency approach in which the target is defined exogenously by political decision-makers on the basis of available scientific information, but without strict economic rationalisation". However, the "scientific information" that can help set tariff levels is notoriously uncertain.

In the IPCC Special Report on Renewable Energy, four main approaches to setting FITs levels are identified: payments based on the levelled cost of renewable electricity generation (LCORE); payments based on the value of renewable electricity generation; payments determined through auction mechanisms; and "simple fixed-price incentives based on neither generation costs nor notion of value" (Mitchell et al., 2011, p. 50).

Theoretically, the level value of renewable electricty generation could be determined on the basis of its environmental benefits – at least, it should be according to French law (Loi n°2000-108, article 2). But such a basis is hardly practicable (Haas et al., 2007, p. 8; interview 12), and FITs levels are in practice usually based on estimated production costs relative to electricity price (Haas et al., 2007, p. 8). Relying on "specific generation costs" and designing FITs "to make it possible for efficiently operated renewable energy installations to be cost-effectively installed" is often considered the most effective and practicable option (Couture and Gagnon, 2009, p. 955).

4.3.1.2. Elusive information on costs

However, reliable information on the current and projected cost of renewable energy technologies and projects is not simple to obtain – even more so for photovoltaics, considering the dramatic evolutions in the prices of photovoltaic module since 2008 (Bazilian et al., 2013).

The information necessary to determine FIT payment is not only difficult to track; policy-makers often depend on industrial actors and projects developers to obtain it. These stakeholders may have interest in high FIT payments, which means that there is a significant risk of regulator capture. Finon (2008, p. 15-16, author's translation) outlines that "the influence of interest groups and industrial actors who want to develop in this technological domain is noticeable on all the characters of the mechanisms: level, duration, sequential evolution of price during the contract, price decrease from one year to the next". Lesser and Su (2008, p. 986) also stress the challenge "to efficiently elicit truthful information for this industry without undue administrative burden" in a situation where "the right information set is fundamental to the effectiveness of a FIT structure".

This dependence puts regulators in a difficult position, as they not only have to guess which FIT level is appropriate, but also to justify why they do not rely entirely on the data provided by stakeholders.

> "Basically, how do we calculate tariffs? We're a bit bereft, because we have data on the decrease of panel, well, of photovoltaic modules, photovoltaic cells, but we never have… no industrial or project developer is ever going to tell us: 'my project works at 1 € per Wc installed, or 2 € per Wc installed'. People will never tell us that, or if they do, that's not the numbers they have, that's other numbers. And we can estimate, but we're never precise at 20 or 30%. So at some point there's a phase where we suggest something, see the reactions, and then we adjust, there's a phase of discussions-negotiations. That's a shame, but that's the way it is in many sectors. People like to think that the administration is able to perform expert calculations and say: 'well, actually the tariff must be like that', that's… no." (Interview 15)[108]

[108] "En gros, comment on calcule les tarifs ? On est un peu démunis, finalement, parce qu'on a des données sur la baisse du coût du panneau, enfin du module photovoltaïque, des cellules

4.3.2. Adjusting feed-in tariffs

4.3.2.1. Keeping up with the evolutions of photovoltaic markets

The difficulty in obtaining reliable information on costs is further heightened by the fact that the costs of renewable electricity technologies and production evolve quickly, and are influenced by the level of support. This implies that it is not enough to set FITs at the right level; they have to be (almost constantly) adjusted so as to follow market evolutions. In the case of photovoltaics, these have been particularly quick and hard to predict, especially as the combination of high generation subsidies in Europe and manufacturing subsidies in China has triggered the expansion of the Chinese photovoltaic modules industry, resulting in drops in photovoltaic module prices (Jäger-Waldau, 2013). The dynamism of the global photovoltaic industry virtually leaves no time for the "trial and error process" through which FIT levels would in theory be adjusted (Ringel et al., 2006, p. 9-10).

In such a context, the stability of feed-in tariffs is thus "also an Achilles' heel: a fixed, long-term price – or a price series with a built-in technology adjustment factor – will almost certainly deviate from realized market prices by greater amounts over time, thus distorting wholesale and retail energy markets" (Lesser and Su, 2008, p. 983).

However, adjusting FIT levels is a complicated matter, especially when it has to be done often. When decided by policymakers to follow changing market trends, FIT adjustments indeed become hard to predict and can lead to "stop & go". This has been shown to generate risk and uncertainty and undermine investors confidence, and hence to be counter-productive in terms of market support (Mitchell et al., 2011). As the SRREN puts it,

> "the higher the frequency of adjustments […] and the higher the degression rate in case of overshoot, the greater the control of support but the lower the stability for investors." (Mitchell et al., 2011, p. 52)

Stepped FIT such as those introduced by the German EEG or the French self-adjusting FIT were devised precisely to meet this challenge, and are examples of the "design features" that have been "inherently built into the schemes to ensure they are flexible enough to account for changes in the development of costs and technologies and so minimise the financial support granted" (European Commission, 2013a, p. 3). However, they have not been sufficient to spare the need for reform and combining stability and flexibility remains a crucial challenge with no pre-printed solution.

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photovoltaïques, mais on n'a jamais... aucun industriel ni aucun développeur de projet ne va nous dire : 'ben moi, mon projet il sort à 1€ du Wc installé, ou à 2€ du Wc installé'. Ca, les gens ne nous le diront jamais, ou quand ils nous le disent, c'est pas les chiffres qu'ils ont eux, c'est les autres chiffres. Et nous, on peut faire des estimations, mais on n'est jamais précis à 20 ou 30 %. Donc quelque part après il y a la phase où on propose quelque chose, on regarde comment ça réagit, et puis on ajuste, y a une phase un peu de discussion-négociation. C'est regrettable mais c'est comme ça dans beaucoup de filières finalement. Les gens qui s'imaginent que l'administration est capable par des calculs savants d'arriver à dire : 'ben en fait le tarif ça doit être ça', c'est... non."

4.3.2.2. Avoiding over-stimulation

The reason why mismatches between policy incentives and actual market conditions are a problem is that they entail under- or, more frequently, overpayment and over-stimulation of the market (Mitchell et al., 2011, p. 52). The latter has been the main problem with photovoltaic support in Europe in recent years, and support scheme design now focuses on devising ways to enhance control of market growth.

Excessive feed-in tariffs lead to over-stimulation of the market because they provide over-payment of photovoltaic electricity producers; since the cost of FIT policies is borne collectively (usually by electricity users), the issue of controlling market growth is mainly a distributional issue. Feed-in tariffs have thus been criticised for weighing rather heavily and lastingly on electricity prices and generating a form of tax (Lesser and Su, 2008, p. 982):

> "Concerns about distributional impacts of renewable energy policies on poorer consumers arise most frequently in countries where FITs have led to significant increase in RE capacity, particularly for relatively high cost technologies such as PV, because of resulting increase in total electricity costs." (Mitchell et al., 2011, p. 58)
>
> "Even the highly successful German FIT – successful when measured in terms of renewable capacity developed – has been criticised for its adverse impact of electric rates and retail customers increasingly protest its implementation." (Lesser and Su, 2008, p. 982)

The design of the compensation mechanisms (in France and Germany, a levy on electricity consumption) is thus a crucial and highly sensitive issue.

In fact, the more secure the investment conditions a FIT scheme provides, the higher the collective risk of seeing the market deviate and lead to high costs. Schmalensee insisted on this characteristic of FIT systems, shedding a new light on their supposedly risk-free nature:

> "The clearest theoretical argument for FIT's superiority over RPS is that guaranteeing the price at which a renewable generator can sell removes electricity market risk from investors in renewable generation, so that more capital can be raised per dollar of subsidy expense. But this bang for the buck measure neglects the impact on actors other than investors in renewables and those who pay subsidies. Measures that remove market risk from one set of players may simply shift to others and thus not reduce the risk to society as a whole." (Schmalensee, 2012, p. 50)

Though he regrets that "overall social risk seems to have received little attention from analysts", he notes that simple design features can reduce the riskiness for society of policy measures – for instance a cap on the maximum quantity of electricity that can benefit from the guaranteed price. Such measures, however, reduce investment security and visibility and can even been harmful to market development, so it is a difficult balance to strike.

4.3.2.3. Balancing private and collective risks and benefits

Since the 2008-2010 FIT crises, finding and maintaining a balance between investor security and social cost has become an increasingly important focus of photovoltaic support policy. To an extent, risk reduction for everyone (government, investors, electricity consumers, taxpayers), or rather, the quest for as equitable an allocation of risks as possible, has become a determining criteria in designing and amending RES-E support policies.

Indeed, though the swift increase in renewable electricity generation capacity in the mid to late 2000s has reassured the EU about the capacity of Member States to meet their 2010 and 2020 targets (European Commission, 2011b, 2011c), progress has now slowed down. European countries were successful in achieving rapid growth in renewable electricity generation, but the very conditions of this success, that is incentives that shifted the burden of uncertainty from investors to governments and/or energy consumers, do not appear sustainable. Since they imply that the costs and risks of investing in a non-stabilised technology are born collectively and not by private investors, feed-in tariffs raise distributional issues.

These led to attempts to control the quantity and quality of projects able to benefit from feed-in tariffs. In terms of quantity, stepped FITs, such as those used in Germany or in France, are meant to limit the costs of feed-in tariff schemes; in France, they explicitly include a cap on the volume of installation, since the decrease is calibrated to accommodate the annual installation of 500 MW.

In terms of quality, these distributional issues have led policymakers to refine FIT schemes in order to target market development to sectors deemed more equitable, more promising for society as a whole, or less speculative. This trend is particularly striking in France, where FIT categories have proliferated since 2010 (cf. Chapter 4 below, Annexes 3 and 4).

Distributional issues have been even heightened by the realisation that feed-in taroffs were not so successful in triggering industry deployment and job development in Europe – even in Germany, the industrial benefits of photovoltaic support have been contested (Frondel et al., 2008). Because of the expansion of the Chinese photovoltaic manufacturing industry, cheap imported panels flooded European markets, undermining the emerging industry. FIT systems are clearly more successful in supporting photovoltaic electricity producers and project developers than in developing photovoltaic components manufacture. In France, feed-in tariffs have been blamed for subsidising the Chinese industry. To remediate to this, recent attempts have been made at incorporating mechanisms to support the European and domestic industry into FIT schemes. For instance, Italy and later France introduced premiums for photovoltaic installations including components produced in the EU.

However, as noted before, recent reforms of FIT schemes have negatively impacted investment. The challenge is thus not only to allocate the cost of the development of photovoltaics in a more acceptable way, but also to sustain the initial market growth while guaranteeing it is done in a politically reliable and economically viable/efficient manner.

Because it seriously damaged investor confidence, the recent turmoil made it a crucial issue: the focus of RES-E policy is now on restoring a reasonable level of security for investors while avoiding overshoot. This concern also translates into increased pressure from the Commission for Member States to reduce non-economic barriers as an alternative way to reduce risks.[109] The current position of the European Commission reflects this change in focus:

> "The financial crisis also affects these developments more than was anticipated by Member States in their national renewable energy action plans; EU countries face a different financial risk rating today and that has had a further negative impact on investments in renewable energy." (European Commission, 2013b, p. 6)
>
> "As investor and market confidence in the renewable energy sector depends heavily on the regulatory framework, the reform of support mechanisms must be managed carefully." (European Commission, 2013b, p. 9)
>
> "The changed economic climate has also clearly had an impact on the development of new renewable energy projects. One aspect is the increased cost of capital in general. Another aspect is the increase in risk resulting from Member States changes to support scheme. The Commission's planned guidance on support schemes and reform is intended to ensure that such support is cost effective and helps integrate renewable energy production into the energy market." (European Commission, 2013b, p. 32)

4.3.3. Current approaches to support to electricity from renewable energy sources (as of 2013)

4.3.3.1 New EU guidelines

Recent developments are characterised by a turn to a more pragmatic approach to RES-E support. At the time of writing, the European Commission was preparing a Communication on "Delivering the internal market in electricity and making the most of public intervention", which will be accompanied by the "European Commission guidance for the design of renewables support schemes". In an October 2013 draft version (European Commission, 2013c), the Commission admits that "reform is indispensable, as support schemes should adjust to the falling cost of renewables" (p. 2) but insists that it should be carried out carefully so as not to harm the market, stressing that "the manner in which the reform is carried out can influence the costs of renewables" (p.2). It thus sets to explore "best practices in managing the reform of support schemes and in designing the support framework for the development of renewables in a manner fully integrated with the market to increase their effectiveness" (p.2).

As it did previously, the Commission draws lessons from recent experience, and particularly from the comparisons of the effects of the rapid rhythm of reforms in many EU countries. Besides, in its assessment of instruments and best practices, it particularly stresses the need to expose renewable energy producers to electricity market prices, so as to complete the integration of electricity from renewable energy sources in the market.

[109] "[...] administrative burdens and delays still cause problems and raise project risk for renewable energy projects; slow infrastructure development, delays in connection, and grid operation rules that disadvantage renewable energy producers all continue and all need to be addressed by Member States in the implementation of the renewable energy Directive." (European Commission, 2013b, p. 32)

4.3.3.2. The comeback of auctions

The draft indicates yet another shift in the European Commission's preferred RES-E support instrument. As a result of the many difficulties encountered under feed-in tariff regimes and of their "major negative features"[110] that "have been revealed in recent years" (European Commission, 2013c, p.11), tariffs have now fallen from grace:

> "The Communication recommends that feed in tariffs are phased out and support instruments that expose renewable energy producers to market price signals such as feed in premiums are used." (European Commission, 2013c, p. 11)

The alternative favoured to feed-in tariffs is no longer a TGC system. Instead, the Commission turns back to tendering and auctions systems. Following the poor performance of the UK NFFO and the French "Eole 2005" auction programme in the 1990s, tendering schemes were barely considered an option in the 2000s. Yet, the Commission now advocates a combination of auctions and premiums to further drive RES-E development:

> "For renewable electricity, if used with feed in premiums schemes and in a power system with adequate infrastructure, well-designed auction system should provide the most cost-efficient for delivering renewables. […] Auctions are also a self-regulating, subsidy phase out mechanism, since competitive bidding with clear and certain rules will reward low cost technologies and eventually approach zero, as technology costs reach grid parity." (European Commission, 2013c, p.5-6)

Conclusion

In this chapter, I have retraced the constitution and gradual refinement of feed-in tariffs for PV-generated electricity as political market *agencements*. In particular, I have shown how they emerged as part of the EU renewable energy policy arsenal with the twin objectives of stimulating innovation in renewable energy technologies and of nurturing and expanding a market space for electricity from renewable energy sources. On the basis of document analysis and considering the general evolution of EU renewable energy policy, I have identified four phases in the European career of feed-in tariffs: the emergence of "proto-FITs" followed by their integration into legislation; the structuration of EU-wide renewable energy policy around the objective of market integration; a period of explicit scale-one experimentation around RES-E support instruments; and a phase of turbulence and reform focused on the management of the overflows triggered by feed-in tariffs for PV-generated electricity.

Relying on the conclusions of chapters 1 and 2, can we draw a schematic picture of the career of FITs-as-*agencements* in Europe? What dynamics of stratification and actualisation are at play in their evolutions? How are the political and market dimensions of feed-in tariffs articulated, and how has this articulation evolved? Focusing on the qualities of feed-in tariffs as *agencements*, I suggest the following interpretation of their evolution. This interpretation is of course schematic, but it stresses that the division between markets and politics is at stake in the career of feed-

[110] These include "the impairment of flexible and liquid markets, limiting growth to certain technologies and sizes of installations, and the difficulty in setting appropriate tariff levels and in adjusting such tariffs" (European Commission, 2013c, p. 11).

in tariffs. Its main shortcoming is that it does not delve into the mechanics of EU institutions and policy processes, and thus does not account for the differences between the Commission, the Parliament and the Council, not to mention the negotiations and divergences among different DGs within the Commission.The study of the evolution of feed-in tariffss within European institutions in more details may lead to a very different picture, and would certainly provide an interesting addition to this broader sketch.

The mechanisms that evolved into feed-in tariffs were initially crafted in reaction to the development of wind power in Germany and Denmark. This grassroots development mainly driven by cooperatives resulted from a form of political activism and innovation, which purchase agreements aimed at incorporating in the extant electricity system, as their calibration on the basis of avoided costs suggests. Proto-FITs mechanisms were market *agencements* designed to channel the consequences of political innovations by pacifying electricity from renewable energy sources as a commodity exchangeable on the existing electricity market without affecting it. They thus clearly leaned toward stratification.

However, with the emergence of FIT legislation in the early 1990s and the formulation of European renewable energy policy, feed-in tariffs took on an explicit political character. They translated the new political objective of developing electricity from renewable energy sources and therefore were designed to contribute to the transformation of the electricity markets and of the energy sector. For instance, this change in the *agencement* of feed-in tariffs shows in the shift from avoided costs to external cost in the calibration of feed-in rates. In that, they were supposed to drive a dynamic of actualisation, but only to a limited extent.

It is over the course of the second period I identified that feed-in tariffs, and more generally RES-E support policies, were constituted as devices for both the promotion of renewable energy *and* for the achievement of the internal market for electricity. As such, they were articulated as both market and political *agencements*. As market *agencements*, RES-E support instruments were meant to correct the lack of internalisation of externalities related to environmental protection and to innovation. They were supposed to trigger change, or rather to accelerate changes expected to happen anyway, but with the ultimate objective of correcting and improving a market that was already instituted. As political *agencements*, they are supposed to be calibrated according to the objectives for renewable energy development, and as such embody the outcome of political deliberation on the issue. But, further than that, they delegate the fulfilment of these objectives to markets, and specifically to the internal market for electricity. They articulate the issue of renewable energy development as something that should be managed through the functioning of market. As a result, not only as market *agencements* but *as political agencements as well*, they are expected to correct existing market failures and “level the playing field” but not to interfere with the functioning of the market, that is to say not to hinder market integration and not to generate additional distortions. It is on those grounds that feed-in tariffs were initially met with suspicion from the European Commission.

With the two core objectives of renewable energy support (i.e. creating markets for lectricity from renewable energy sources to increase RES-E production capacity and stimulating innovation) unchanged, the focus gradually shifted from the achievement of market integration to the improvement of RES-E support instruments. I have described the 2000s as a phase of scale-one experimentation during which instruments have been refined and sophisticated so as to better perform their market and political functions and in particular to adjust to the market and technological evolutions they spark. The issue of instrument calibration and re-adjustment was thus articulated as something that could be managed through instrument design without need for any further political negotiations: it was, essentially, a matter of economic and policy-design expertise.

This was thus a phase of innovation, learning and exchange of best practices on instrument design, but it took place in stabilised framework: the overarching objectives of RES-E policy were not questioned, and the division between market-relevant and politics-relevant issues was established. During this period, RES-E support instruments can be considered as triggering actualisation insofar as they encourage a certain kind of proliferation and innovation (in instrument design, in technologies, in installed capacity). But this actualisation took place in a very structured manner, and was closely monitored and registered by EU institutions and researchers. A network of expertise and a set of monitoring devices were established to track the effects of instruments and to improve these instruments accordingly, but it did so within established political and market frames.

Indeed, as it appeared increasingly clear in the late 2000s, the experimental setting put in place at the EU level only registered part of the effects of support to electricity from renewable energy sources. It was not equipped to take into account and manage the overflows they triggered. This was especially true for FIT-supported photovoltaic markets. Even though feed-in tariffs for PV-generated electricity worked well in terms of installed capacity and seemed to trigger cost reductions, they also led to an unintended – and hard to register and monitor – proliferation of new and unexpected actors, entities and ways to make the most of the opportunity constituted by feed-in tariffs. These included for instance Chinese photovoltaic panels manufacturers, farmers exploiting their large available sunlit roof surfaces, or investors attracted by the security of investment in photovoltaics in the context of the financial crisis. The rapid and overflowing growth of photovoltaic markets led to feed-in tariffs for PV-generated electricity being challenged as both market and political *agencements*. The market framings they established as well as the articulation and mode of management of issues they provided were re-opened and re-considered in many countries. The uncontrolled dynamics of actualisation triggered by feed-in tariffs for PV-generated electricity then called for actualisation and innovation in their design, logic and management. This crisis was very different from the previous experimental phase, since the devices for stabilisation and channelling of novelty were not readily available and had to be developed along the way. By zooming in on the French case, the following chapter will provide an example of how this situation was tackled.

Chapter 4

Political FITs

> "I had thought I could put a process in motion and control it at every turn – even stop it if I wanted to. And now the frightening conviction grew in me that such a process may become a thing in itself, a person almost, having its own ends and means and quite independent from its creator. And another troublesome thought came in. Did I really start it, or did I simply not resist it? I may have been the mover, but was I not also the moved?"
> John Steinbeck—*The Winter of our Discontent*

In many respects, the trajectory of photovoltaics in France is in line with the European history described in the previous chapter. Feed-in tariffs for PV-generated electricity were set up in 2002 as a way to achieve renewable electricity production objectives set by the EU; they triggered a rapid expansion of photovoltaic markets, and their unexpected effectiveness led to their brutal reform in 2010-2011. However, the French case is peculiar insofar as feed-in tariffs turned photovoltaics almost directly from a promise into a problem. Photovoltaic electricity was not really taken into account until the pace of FIT-driven market expansion led the government to intervene in 2010, first through punctual attempts at re-adjusting feed-in tariffs, and then by deciding a three-month moratorium on feed-in tariffs, thus triggering a political and market crisis. How were feed-in tariffs for PV-generated electricity set up in France? What was their role in turning photovoltaics from a promise into a problem? How can the crisis that erupted in 2010 be accounted for, and what effects did it have?

Here, I relate the articulation of photovoltaics as an issue in France, from the implementation of the first feed-in tariffs for PV-generated electricity in 2002 to the reforms of early 2013, with a focus on the years 2008 to 2012. An issue, as Callon defined it, "is a problem, but it is also a way in which what can no longer be contained flows away (issue of blood, outflowing) and thereby becomes, by the problems posed, a question for debate" (Callon, 2004, p. 132). This chapter indeed focuses on the way French feed-in tariffs triggered effects that they could no contain, leading photovoltaics to "flow away" and deploy as a matter of concern. Its primary aim is to clarify the crisis that culminated with the moratorium and the *consultation* on photovoltaic policy that took place between December 2010 and March 2011. To do so, I build on the description of feed-in tariffs as political market *agencements* sketched in chapter 2, on an analysis of legislative and regulatory texts on photovoltaic policy, and on a set of interviews with actors of the French photovoltaic sector.

The chapter is divided in two parts. In the first part, I focus on the history and design of French feed-in tariffs for PV-generated electricity and on the evolution of the *agencements* they articulated. I detail their origins and their set up as market instruments meant to achieve specific political and economic objectives. I review successive reforms of FIT schemes and their consequences in terms of framing of market transactions and political actions.

The second part follows the overflows of the FIT-photovoltaics *agencement* and their management. It first shows how the opportunity framed by polyvalent feed-in tariffs applicable to any type of photovoltaic projects and by their misalignment with the evolution of photovoltaic module costs led to an unanticipated and hardly monitored proliferation of photovoltaic projects. In turn, this overflowing market activity triggered government intervention that drew the focus on the political effects of feed-in tariffs. I show how this intervention constituted the actors of photovoltaic sector as a public – that is to say as political actors – and led to the articulation of photovoltaics as a political issue. FITs played a crucial role in sparking both a proliferating market and a political moment. However, in analysing the outcome of the *consultation*, I show that feed-in tariffs were also used to narrow down the space for market activity and innovation and to stifle possibilities for political intervention and discussion. The chapter thus explores how French feed-in tariffs have been used alternately as devices to generate economic – and to an extent political – mobilisation around photovoltaics, and in attempts to strictly contain the development of photovoltaics.

Section 1 – A history of feed-in tariffs for PV-generated electricity in France

1.1. 1990s-2000s: towards a French renewable energy policy

1.1.1. 1990s: considering policy options

The French government started considering options for supporting electricity from renewable energy sources in the 1990s. At the time, electricity from renewable energy sources was purchased by EDF on a tariff determined on the basis of marginal avoided cost (Maigne et al., 2008; Interview 39). Avoided costs were calculated by EDF, and not very generously so (Interview 39). However, neighbouring countries were starting to promote renewable energy deployment, and the mechanisms they used, especially feed-in tariffs, began to attract interest in France.

Several reports published in the early 1990s reviewed existing support schemes and stressed the need for France not to go against the flow[111] (Brosse, 1992 as quoted in Evrard, 2010, p. 295): prefect Claudius Brosse published a Report on Renewable Energies in December 1992 (Brosse, 1992), and economist Dominique Finon reviewed

[111] “Ne pas faire cavalier seul” in the original text.

mechanism for supporting the production of electricity from renewable energy sources especially in the US and Italy in a report commissioned by the Prime Minister (personal communication, 2013).

These reports paved the way for the National Debate on Energy and Environment that took place in 1994. Jean-Pierre Souviron's report on this debate proved relatively open to renewable energy, considering the internalisation of external costs as one possible option for renewable energy support (Souviron, 1994; Evrard, 2010, p. 300). This resulted in the setting of a working group on the conditions of purchase of electricity produced by cogeneration or from renewable energy sources that was led by the *Direction générale de l'énergie et des matières premières* (DGEMP)[112] (Evrard, 2010).

Inspired by the German, Danish and Californian examples, the emerging renewable energy sector as well as experts from the *Agence de l'Environnement et de la Maîtrise de l'Energie* ADEME)[113] were strongly in favour of tariff-based incentives that would be able to remunerate renewable energy producers at higher rates than the "avoided costs" system (Evrard, 2010, p. 300). As Evrard narrates,

> "An expert from the ADEME carried out comparative analyses on the basis of the Danish, German and Californian experiences. He observes that the common feature of these different success stories for renewables, and especially wind power, lies in their incentivising tarification system. During a conference organised in 1991, he advocates "feed-in tariffs" systems that, according to him, made the uptake of emerging renewable energy sectors possible." (Evrard, 2010, p. 300, author's translation)[i]

Such was the position of ADEME experts and renewable energy developers during the debates that took place within the DGEMP working group, which mainly focused on wind power development (alternative renewable energy sources were not on the agenda at the time).

EDF, on the other side, was rather opposed to a feed-in tariff system and advocated calls for tenders instead. As Evrard remarks, they justified their stance not in terms of installed capacity deployment, but on economic grounds, arguing that calls for tenders were more likely to trigger a process of cost reduction:

> "While all actors seem to admit the greater effectiveness [of the feed-in tariff system] in terms of installed capacity, EDF insists on economic aspects, in particular on the decrease in prices that the call for tenders mechanisms should trigger." (Evrard, 2010, p. 301, author's translation)[ii]

The government eventually opted for calls for tenders, and the outcome of this process was the "Eole 2005" program, which was launched in 1996 with a target of 250 to 500 MW of installed wind power by 2005 (Evrard, 2010, p. 301).

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[112] General direction for energy and raw materials, a former branch of the French administration that was part of the Ministry for Industry.

[113] Environment and Energy Management Agency. The ADEME is a public institution created in 1991 and depending from the Ministry for Ecology. It contributes to the implementation of environmental and energy management policy as well as to the development of expertise and public information on environmental and energy issues.

1.1.2. 2000: The "Modernisation of the Electricity Public Service" Bill

The issue of renewable energy support resurfaced in 2000. The 1996 Directive on the internal electricity market was transposed by the *Loi sur la modernisation du service public de l'électricité* (Bill on the modernisation of the electricity public service), which was passed on 10 February 2000 under a left-wing majority (Loi n° 2000-108, 2000).

The bill addresses with renewable energy development insofar as it defines it as one of the objectives of the "electricity public service":

> "contribut[ing] to independence and security of supply, air quality and the fight against the greenhouse effect, to the optimal management and development of national resources, to the control of energy demand, to the competitiveness of economic activity and to the control of technological choices for the future, as well as to the rational use of energy." (Loi n°2000-108, article 1er, author's translation)

Renewable energy development falls within this scope: public support to renewable energy is thus supported as long as it contributes to these objectives. The law then shapes the future development of French renewable energy policy by delimiting it as a policy area and determining the instruments, procedures and actors relevant to it. It defines the way objectives are to be set up, the policy instruments available to attain them, and allocates competencies and obligations regarding their implementation.

From 2000 onwards, objectives for the production of electricity from renewable energy sources, as those of any electricity generation source, are to be set and regularly revised in the *"Programmation pluriannuelle des investissements de production d'électricité"* (PPI)[114] elaborated by the Minister in charge of energy and presented to the Parliament (article 6). The law also introduces two mechanisms that can be used to support electricity from renewable energy sources. First, it creates a purchase obligation for the electricity produced by RE installations under 12 MWc (Loi n° 2000-108, article 10; cf. Chapter 2, 2.1.).

The detailed conditions of implementation of the purchase obligation for each relevant source of electricity are to be defined by the economy and energy ministers by *décret*. In the event that it is no longer in line with the PPI's objectives, and provided that ongoing contracts are maintained, the obligation may be "partially or entirely suspended by *décret* for no longer than 10 years" (Loi n° 2000-108, article 10).

Calls for tenders are defined as a possible recourse "when production capacities do not correspond to the objectives of the *programmation pluriannuelle des investissements*, especially those regarding generation technologies and the geographical location of installations" (Loi n° 2000-108, article 8).

The costs incurred by these devices are compensated through the *Contribution au Service Public de l'Electricité* (CSPE),[115] which is a form of levy on electricity

[114] Pluriannual planning of investments in electricity generation. It defines the objectives for the evolution of electricity generation, usually considering the coming five to ten years.
[115] Contribution to the electricity public service

consumption created by the 2000 bill to fund the various missions of the electricity public service, as defined by law.

The CSPE is paid by all final electricity users as a fix amount per kilowatt-hour. With a few exceptions, it is recovered by grid operators and electricity suppliers, thus directly impacting electricity bills. It is transferred to the *Caisse des Dépôts et Consignations* (CDC),[116] which then reimburses the costs supported by electricity suppliers. The level of the CSPE is determined each year by the *Commission de Régulation de l'Energie* (CRE)[117] on the basis of the expenses declared by utilities for the previous years; it is then confirmed by a ministerial *arrêté* (CRE website).

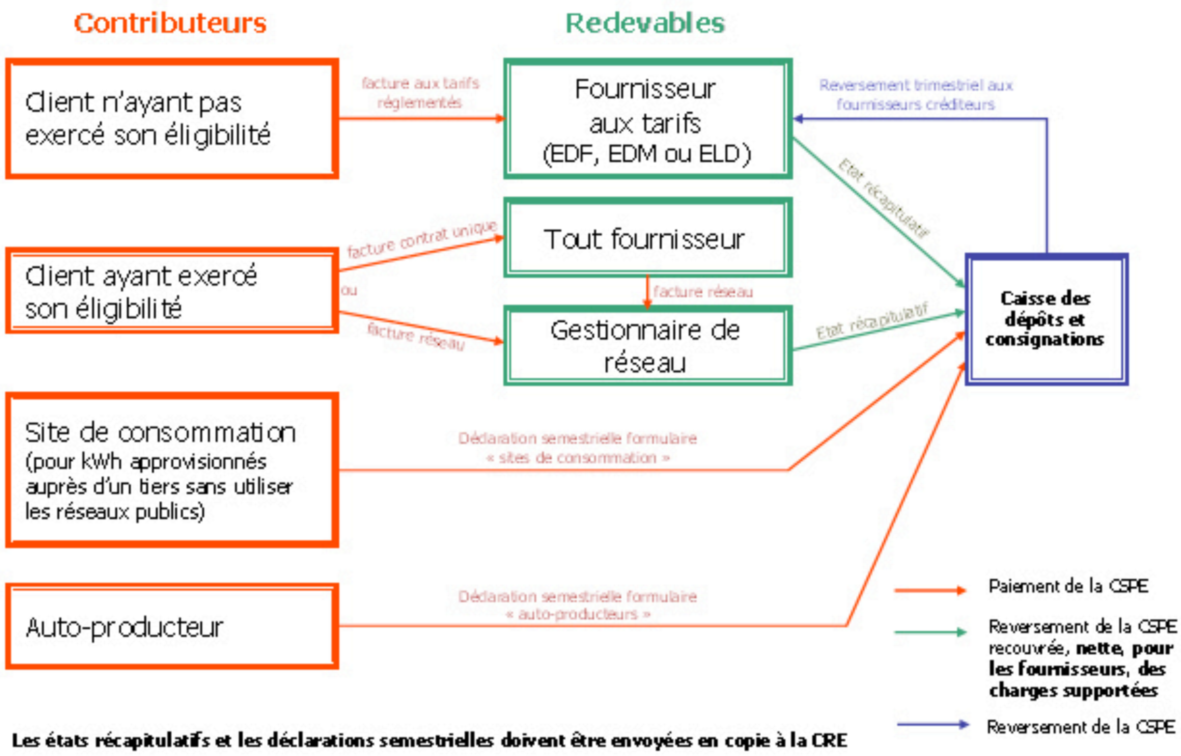

Figure 10 The organisation of the CSPE levy (retrieved from the CRE website: http://www.cre.fr/operateurs/service-public-de-l-electricite-cspe/mecanisme#header, last accessed 29/10/2014)

In the 2000 framework, the purchase obligation is defined as the default instrument for renewable energy support. As one interviewee noted, it is a rather unusual and peculiar mechanism:

> "Then, one needs to go back to the basics of the purchase obligation: energy policy is determined by public authorities, taken care of by a private firm, and funded by taxes – because it is a levy. So you have a rather original device. [...] I don't think it exists in any other sector in France." (Interview 35)[iii]

Indeed, through the purchase obligation, the implementation of renewable energy policy objectives is delegated to market actors (namely, renewable energy producers, electricity

[116] The *Caisse des Dépôts et Consignation* is a public financial group serving missions of general interest and placed under the control of the Parliament.
[117] Commission for the Regulation of Energy.

suppliers, grid operators, and electricity users) whose agencies are framed asymmetrically. The CRE, as an independent regulator, is responsible for controlling and calibrating the *agencement*. Yet, the government retains significant leeway and remain the ultimate arbiter. Relevant ministers indeed control (with the mediation of democratic political procedures) the objectives that serve to calibrate renewable energy support: the government defines them through the elaboration of the PPI, and can revise them or even reinterpret the objectives of the electricity public service. The law provides room for manoeuvre for them to modify renewable energy support accordingly, by suspending purchase obligations or using calls for tenders instead.

1.2. 2000-2005: Introducing feed-in tariffs

The 2000 law set the general framework for French renewable energy policy, creating a legal basis of feed-in tariff schemes, while EU-level commitments gave it a direction. From then on, renewable energy development policy clearly has revolved around the facilitation of specific market transactions, hence the creation of new markets. There was still a long way to actual instruments (and market) creation), and the socialist-green government put the issue on the agenda in early 2000. Prime Minister Lionel Jospin spoke at the annual meeting of the *Syndicat des Energies Renouvelables* (SER),[118] declaring that:

> "We need to develop a real renewable energy industry. […] The point is no longer to subsidise your sector so as to maintain it as backup, but to *help you conquer markets* which importance has been underestimated for too long." (as quoted in Cochet, 2000, p. 15, author's translation, emphasis added)[iv]

1.2.1. The "Cochet Report"

1.2.1.1. Advocating feed-in tariffs

In April of that same year, Prime Minister Lionel Jospin commissioned Green Member of Parliament Yves Cochet to write a report on "the strategy and means to put in place to accelerate the valorisation of renewable energy in our country". In this report, Yves Cochet (soon to be appointed Minister for the Environment) reviewed existing renewable energy support schemes as well as current European regulation. His conclusions are similar to those prevalent in the literature on electricity from renewable energy sources of the time: calls for tenders have proven disappointing and ill-suited to their purpose, Cochet argues – Eole 2005 had led to the installation of no more than 70 MW (Evrard, 2010; Nadaï, 2007), the setting of a European-wide quota system is the most likely medium term hypothesis, and, in the meantime, "guaranteed price systems are the only able to speed up the development of renewable energy and to enable them to reach industrial maturity" (Cochet, 2000, p. 21, author's translation).[v]

[118] Renewable Energy Syndicate, one of the main associations representing the interests of renewable energy firms and industry in France.

To draw this conclusion, Cochet referred to economic arguments,[119] to the specificities of electricity from renewable energy sources[120] as well as to the German success[121] and the recent expertise from the European Commission.[122] The rationale for feed-in tariffs appeared to combine economic theory, technological expertise, and policy experience.

1.2.1.2. Recommendations on FIT design

The report then gives recommendations on the design of support schemes. Though they should be articulated around "economic and financial" mechanisms (p. 36), Cochet notes, the enabling institutional environment (i.e. additional measures) is crucial to their success, "even more so for emerging technologies" (p. 36). Cochet thus proposes a rather comprehensive policy mix, taking into account the specificities and degree of maturity of each source of renewable energy.

In particular, he provides indications on the design of feed-in tariffs, especially regarding the challenges posed by their calibration: setting the "right" price and adjusting it to cost evolutions, and controlling market growth.

> "These tariffs need to be **simple, clear and accessible**. Their level must be set according to the real and expected effects on the sector, and **not on the basis of external elements related to the current structure of the electric system**, such as 'long term avoided costs' used in usual calculations. They need to be accompanied by **mechanisms for indexation and revision** that are transparent, announced ahead and stable over a period long enough to allow for the insight necessary to finely assess their impact." (Cochet, 2001, p. 101, author's translation, emphasis in original) [vi]
>
> "One way to *address the legitimate concern that a quantitative overflow* may threaten to be difficult to control in the case of a purchase obligation, would be to cap either global annual installed capacity (in MW) or global annual produced and purchased electricity

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119 [Calls for tender advocates] "confuse the notion of cost with that of cost: while the latter reflect the state of power relationships at a given moment in the context of a trade negotiation between a seller and a purchaser, as everyone knows, they are not necessarily and automatically related to the actual costs borne by either party to the transaction" (Cochet, 2000, p. 41, author's translation) [[Les défenseurs des appels d'offres] "confondent la notion de coût et celle de prix : si ces derniers reflètent comme chacun sait l'état du rapport de force à l'instant T dans le cadre d'une négociation commerciale entre acheteur et vendeur, il n'est pas dit qu'ils soient pour autant et automatiquement en relation avec les coûts, bien réels, supportés par l'une ou l'autre des parties."]

120 [direct price support] "requires a market that is structured and regulated in a way that makes it possible to an extent to administrate the price of energy and to identify a type of actor or a specific level on which to base the mechanism. That is why in practice it is limited to grid-dispatched energy." (Cochet, 2001, p. 37, author's translation) [[Le soutien direct des prix] "nécessite un marché structuré et régulé de telle sorte qu'on puisse y administrer, dans une certaine mesure, le prix de l'énergie et identifier un type d'acteur ou un échelon particulier sur lequel asseoir le mécanisme. C'est pourquoi il est réservé en pratique aux énergies de réseaux."]

121 "the most impressive case is certainly that of wind power in Germany" (Cochet, 2001, p. 42, author' translation) ["le cas le plus spectaculaire est sans nul doute celui de l'éolien en Allemagne."]

122 "Direct price support schemes remain 'the main device for RES-E in Member States', as the Commission itself admits. This is not surprising considering their advantages." (Cochet, 2001, p. 39 author's translation) ["Les systèmes de soutien direct au prix restent, comme l'admet la Commission elle-même, 'le principal outil de soutien de l'électricité SER dans la plupart des États membres', ce qui est logique compte tenu des avantages qu'ils comportent."]

> (in MWh), possibly with quotas for each operator (or type of operator) or for each technology." (Cochet, 2001, p. 100, author's translation, emphasis added)[vii]

1.2.1.3. The promise of photovoltaics

Another interesting feature of the report – which deals with renewable energy in general and only addresses photovoltaics as one source of renewable energy – is the way it frames the purpose of support to grid-connected photovoltaics. Indeed, it views support to photovoltaic electricity as a way to get ready for the mid to long-term promises held by photovoltaics, rather than a means to significantly increase photovoltaic electricity generation. By then, photovoltaics were still very expensive technologies and their mass deployment was not on the agenda in the short term.

> "The priority of such programmes is not for photovoltaics to achieve a significant quantitative contribution to electricity consumption in the short term […], but lies in the will to support the positioning of domestic industry in the prospects of open competition on a market that looks extremely promising by 2020-2030. These programs have actual results, for we observe that photovoltaics are among the most dynamic industrial sectors." (Cochet, 2001, p.118, author's translation)[viii]

At this point, photovoltaic electricity remained rather abstract: it was a promise and a symbol of the future of renewable energy rather than an actual energy source. In that sense, it differed from other renewable energy sources such as wind power, which deployment seemed less distant in time.

The added value of photovoltaics lied in the image of the future they carried for the public, in the dynamism of their still emerging market, in the innovation potential they held for the coming decades – not in the electricity they could generate. Incentives were supposed to amplify these various promises and accelerate their fulfilment, but photovoltaics belonged to a future situated somewhere between 2010 and 2030, at which point they might be able to taken seriously as a source of electricity. Support schemes for photovoltaic electricity were thus meant to arrange its inclusion as a niche product on electricity markets and grids by framing and organising (materially, legally and in terms of procedures) transactions involving photovoltaic electricity. They were designed to do so in preparation for the expected future expansion of photovoltaics, but with no views of mass market development in the near future.

1.2.2. Establishing feed-in tariffs

1.2.2.1. Negotiating the modalities of feed-in tariffs

The Cochet report confirmed feed-in tariffs as the privileged option for articulating renewable energy support schemes. However, the precise design of purchase obligations and the calibration of feed-in rates involved lengthy negotiations between government officials, associations, industry representatives and experts. These were especially long in the case of photovoltaics: it took two years to establish the level of feed-in tariffs for PV-generated electricity.

As was the case a few years earlier, working groups were established to discuss the modalities of FITs. In addition to civil servants, these included representatives for the SER, from NGOs active in the field of renewable energies (notably Hespul), and from EDF. Confrontation within those technical arenas was rather rough. ADEME representatives suggested tariff calculations mechanisms inspired from the German EEG, but EDF was strongly reluctant (Evrard, 2010, p. 314; interview 3). As a member of a NGO who attended discussions recalls,

> "EDF, which by then was still a public firm, really dug in their heels. We took part in all the discussions so we really… And in fact, they did not want to hear of this photovoltaic tariff. It tore them apart, and they were stuck on one point, they did not want it to be over 1 franc. […] 'Don't even think of it, we'll never accept more than 1 franc'. The concrete outcome of this was that the 2002 FIT was set at 0.1525 euro. Which is 1 franc." (Interview 3)[ix]

1.2.2.2. 2002: the first feed-in tariffs for PV-generated electricity

Except for tariff rates, the FIT system that was eventually adopted was very similar to the German model. The *Arrêté du 13 mars 2002* framed the transactions involving grid-connected photovoltaics: it defined in more or less details the good (electricity produced by specific installations under certain limitations), the agencies (eligible producers, buyers), the conditions for market encounters (through a purchase agreement request), the price setting mechanisms applicable, and it described their evolution as well as those of individual contracts (Ministère de l'économie, des finances et de l'industrie, 2002). The agreement was supposed to include all the information relevant for the maintenance of the transaction, and was valid for a period of 20 years.

The basic structure of feed-in tariffs has remained relatively stable since then, insofar as this first FIT system framed the good as "electricity produced from the Sun's radiative energy", created a bound demand for it, and encouraged the development of a loosely defined supply. However, the dynamic of FIT *agencements* as well as the asymmetries between agencies that it created have evolved rather dramatically, as this section will explore. How have successive FIT schemes equipped calculative, and political agencies? How have they organised the calibration of *agencements* and more generally their evolution?

The market *agencement* defined in the *Arrêté du 13 mars 2002* has **three key features** to live up to the challenges of dynamic price adjustment and market containment (Ministère de l'économie, des finances et de l'industrie, 2002). First, the **level of the tariff depends on the date the complete purchase agreement request is submitted**, and is determined according to the following formula:

> "0.95)n x K, where n is the number of years since 2002 (n=1 for 2003) and K corresponds to inflation rates." (Ministère de l'économie, des finances et de l'industrie, 2002)

The tariff level is thus set to decrease by 5% every year.

Second, the **amount of photovoltaic electricity generated by one installation** that can be purchased at the FIT rate is **capped**. "The cap is defined as the product of the installed capacity by a duration of 1200 hours" for an installation in mainland France (MEFI, 2002, article 4). Last, **the size of eligible installations is capped**: 5 kWc for individual households, 1000 kWc for professional and collective buildings, 150 kWc in other situations. A very low rate is applicable for the electricity in excess of production or capacity caps.

The resulting framework was thus relatively secure for investors (it provides the long-term security and profitability that is key to the success of FIT schemes) as well as for the government (the volume of installations and of electricity that can benefit from the FIT is capped to avoid overflows, and the tariff is stepped). Its main shortcoming was the initial rate of 15.25 eurocents per kWh, which was not profitable in mainland France.[123]

1.3. 2006-2010: A series of mis-adjustments and re-adjusments

1.3.1. 2006: Scaling up feed-in tariffs for PV-generated electricity

1.3.1.1. A doubling of feed-in rates

Despite its sound design, the low level of the 2002 feed-in tariff prevented it from triggering any significant development in photovoltaic electricity generation. Not much changed until 2006, when Prime Minister Dominique de Villepin announced that FIT rates would be doubled. The *Arrêté du 10 juillet 2006* modifying feed-in tariffs for PV-generated electricity was published a few days after the one establishing the PPI for 2006-2015, which set the following targets for the development of photovoltaic electricity: 160 MW of installed capacity by 2010 and 500 MW by 2015, mainly located in overseas territories (Ministère de l'économie, des finances et de l'industrie, 2006a, 2006b).

The feed-in rate was increased to 30 eurocents/kWh in continental France and 40 eurocents/kWh in overseas territories. There is not much transparency on the choice of this specific value, but it seems that it was done rather hastily at the Prime Minister's level, mainly as a symbolic gesture (Interview 3). In other words, it does not seem that it relied on specific expertise on photovoltaic markets or on negotiations with industry representatives; the recommendations from the Cochet report, published under a different political majority, seemed long forgotten.

Aside from the change in price, the reform loosened control over the evolution of the FIT-PV market *agencement* by removing several of the framings and mechanisms that had been designed to prevent overflows and take into account the dynamic effects of feed-in tariffs. In particular, the new scheme did not provide for re-calibration mechanisms or procedures. The caps on the size of eligible installations were suppressed, as was the annual 5% decrease. Instead of decreasing, FIT rates were indexed on inflation, which involved a slight increase every year. The cap on the amount of electricity that could be purchased at the FIT price from one installation was maintained, but loosened (from 1200 hours at peak production to 1500), and the delay to

[123] The situation was slightly different in overseas departments and Corsica, where the tariff was twice as high (30.5 eurocents/kWh) and the resource is more important.

put into service an installation was lengthened (from 1 to 3 years after the purchase agreement request).

1.3.1.2. Promoting "Building integrated photovoltaics"

Besides, the reform created a premium of 25 €c/kWh for building integrated photovoltaics (BIPV) (15 €c/kWh in overseas territories). This required that the government defined "building integrated photovoltaics" so as to frame electricity generated from BIPV systems as a specific good. The initial qualification of BIPV was rather broad, as the premium was "applicable when the equipments for photovoltaic electricity generation also ensure a technical or architectural function essential to the building operation" and corresponded to one of the categories listed in the *Arrêté* (Ministère de l'économie, des finances et de l'industrie, 2006a). The BIPV premium was allocated on a declarative basis and not controlled, resulting in a rather lax framework.

The rationale for the introduction of this premium is controversial. The official and most widespread argument is that BIPV – which is more expensive than "standard" photovoltaics – preserves the architectural integrity of buildings. In addition, it is expected to provide an incentive to consider the energy performance of the building as a whole. Last, by creating a niche specific to France, the BIPV premium was expected to create a protected market segment in which a French industry could thrive (Interviews 5, 13, 15). However, according to one interviewee, it can also be interpreted it as a solution put forward by the ADEME to increase FIT rates at a time when 30 c/kWh was not enough to spur market growth, that had the perverse outcome of keeping photovoltaics confined within an expensive niche market (Interview 3):

> "It stems from the fact that 30 cents was not enough at the time. Now we could nearly be happy with it, but for simple systems with standard panels, you had to go up to 45-50 and then you would not need to look for extra subsidies. So the ADEME pushed for this idea [of a BIPV premium], and some clever guys thought, well, we'll do that, and in this way, we keep photovoltaics in a niche."[x]

1.3.1.3. The 2006 *Arrêté* in practice: polyvalent and unbridled feed-in tariffs

These modifications drew critics early on. In particular, the CRE emitted a negative *avis* on the *Arrêté du 10 juillet 2006* (Commission de Régulation de l'Energie, 2006). Assessing the new scheme with regards to European and national legislation, especially the objectives of the *Loi du 10 février 2000*, it concluded that though adapted for continental France in terms of profitability, the proposed FIT was too high compared to the sum of avoided costs, environmental externalities and other positive effects.

Considering the pace of innovation in photovoltaic equipments, the CRE highlighted the risk for it to lead to massive installations of expensive, soon-to-be obsolete systems. It also deemed the BIPV premium too high and not adapted to the diversity of BIPV equipments; this instrument, the CRE stated, could encourage the development of smaller, more expensive installations, and it was questionable whether financing building integration on the basis of architectural motives fell under the scope of the electricity public service. The CRE estimated the cost of the FIT at 50 to 400 million euros a year by 2015, which would represent an addition of 0.25 to 1 euro/MWh to the

CSPE paid by electricity users, on the basis of the government's scenario that aimed at 120 MW cumulative installed capacity in 2010, and 490 MW in 2015 (Commission de Régulation de l'Energie, 2006).

Indeed, in the light of the wealth of literature, experience and expertise on support to electricity from renewable energy sources and FIT design that was available by then, the 2006 FIT scheme is somewhat puzzling. It is a one-size-fit-all, static incentive system that hardly takes into account the specificities of photovoltaics as technologies[124] and the dynamic impact of support on technology costs. A guaranteed price in its most basic form, it provides no way to frame the supply of photovoltaic electricity (hence the demand for FITs). Thus, because it was polyvalent and soon became very generous, this tariff gave no orientation to the development of photovoltaics and instead enabled all types of investors to develop all types of photovoltaic projects. As one interviewee summarised in retrospect:

> "This FIT *arrêté* is not framed. It is not necessarily targeted at individuals, it is not targeted at industries… It does not give any direction to the sector. […] It is very, very open, polyvalent, and does not give any direction to the sector. As a result, every body is going to go for it, with incredible investment return rates – because at the time, you could add support from regional energy agencies, fiscal credit (there is a 50% fiscal rebate on PV material), regional subventions…" (Interview 35)[xi]

As will be detailed in the next section, the effects of the 2006 FIT soon challenged the initial expectations expressed in the 2006 PPI, according to which photovoltaics were unlikely to develop to any significant extent on the mainland (Ministère de l'économie, des finances et de l'industrie, 2006b). The absence of mechanisms that could prevent or at least contain overflows eventually spurred an uncontrolled growth of the number of purchase agreements and photovoltaic projects in France. It took a few years for the market to actually take off, but, by the late 2000s, the situation got difficult to manage for local administrations and grid-operators, who were hardly equipped to process so many project requests.

1.3.2. 2008-2010: Managing the proliferation of grid-connected photovoltaics

1.3.2.1. Regulatory adjustments

From 2006 onwards, a large number of regulatory texts on grid-connectd photovoltaics were adopted, all of which are not detaile din this chapter; a list of official documents related to photovoltaics in provided in Annex 5. Even though feed-in tariffs themselves did not change for a while, a first series of regulations adopted in 2007 and 2008 modified market agencies, encounters and transactions, taking into account the sudden increase in photovoltaic projects and installations. Grid connection procedures and tariffs were modified both on a technical and on an administrative level, making it more expensive for potential photovoltaic producers to connect their installations to the grid (MEDAD, 2007; MEEDDAT, 2008a, 2008b, 2009b).

[124] With the exception of its capacity to be integrated to a building.

Administrative procedures were simplified and clarified. In March 2009, a step in the administrative process was suppressed: small installations (below 250 kWc) no longer needed a *Certificat ouvrant droit à l'obligation d'achat* (CODOA) delivered by regional authorities, which allowed civil servant to pop their heads out of the sea of files and requests they were drowning in (MEEDDAT, 2009a). Some regions and *départements*, such as Midi-Pyrénées, elaborated Regional Doctrines that established common and clarified criteria for the authorisations of medium to large-scale photovoltaic projects (Interview 23; Préfecture de région Midi Pyrénées, 2011). In late 2009, a *décret* and a related *circulaire* simplified and clarified procedures for ground-mounted photovoltaic projects (MEEDDM, 2009a, 2009b). Though such measures relieved the services that managed the various steps in the process of obtaining feed-in tariffs for a project, they paradoxically lifted another of the barriers to market expansion, thus contributing to making matters worse.

> "Then, public authorities were completely overwhelmed by this success, and instead of improving or monitoring the process, suppressed all control devices. Because the suppressed exploitation permits [*autorisations d'exploiter*], which had to be obtained through the Ampère website at the time; they did not have the 30 000 euros needed to update it and make sure it supported the load, so they said: let's suppress exploitation permits. They could not manage CODOAs in the DREAL, so they said: let's suppress CODOAs. Of course, it is so much simpler that way!... well… and so, the system slipped from public authorities." (Interview 35, utility)[xii]

1.3.2.2. Re-targeting feed-in tariffs

Given the design of the 2006 FIT, the only direct way to shift the trajectory was to reform the feed-in scheme. This was done twice in 2010. Both revisions were announced several months ahead, and this episode provides a good example of the uncertainty stemming from the "politically-administered" quality of FITs, which has been criticised by economists and was initially overlooked in assessments of the security provided by FITs. Photovoltaic support was gradually amended throughout the year, until a *décret* in December declared a three-months moratorium on FITs to provide time to think the scheme over (cf. Annex 3). It became clear that the functioning feed-in tariffs for PV-generated electricity relied on an increasing – and increasingly complex – body of procedures, texts, political and administrative supervision and adjustments, information and monitoring, expertise that was not yet fully consolidated, and political negotiations.

1.3.2.2.1. January 2010

In January, the revision had two main purposes: channelling and targeting the development of photovoltaics on the one hand, containing and levelling market growth on the other (MEEDDM, 2010a). To contain the rise in photovoltaic projects and to stem speculation, the delay between the signature of the purchase agreement and the commissioning of a photovoltaic installation was reduced from three to two years. In addition, the applicable tariff rate was to be set when the grid connection request, and no longer the purchase agreement request, was filed – i.e. later in the life of a project. These two measures were supposed to "cleanse" the waiting list by limiting the number of speculative projects filed only to get hold of the tariff opportunity for potential future installations. A regional coefficient was created for large ground-mounted projects, in order to level the distribution of projects over the territory and avoid their concentration in the sunny South of the country.

To channel the development of photovoltaics, the revision put an end to the "one-size-fits-all" design. First, it created several categories of tariffs according to installation size and, if applicable, to the type of building they were installed on. Second, it refined the definition of BIPV so as to make it stricter, and coined the notion of "simplified BIPV" – theoretically, one may think, to take into account cost differentials. This resulted in six distinct categories of tariffs: BIPV on residential buildings, BIPV on educational and medical buildings, BIPV on other buildings, simplified BIPV, small non-BIPV projects and large non-BIPV projects.

All the tariffs were reduced by 12% to take into account the evolution of photovoltaic module costs. Two categories underwent an additional decrease that was meant to steer investors away: "BIPV on other buildings" and "simplified BIPV". In short, the revision was an attempt to requalify the type of goods eligible for FIT by taking into account the actual arrangement of the photovoltaic system generating the electricity put on the market, used a proxy for the kind of project. By framing more precisely the good concerned by the FIT *agencement*, the revision constrained suppliers and thus defined a new balance in the *agencement*.

The last two categories in fact comprised the majority of projects in terms of expected capacity: they represented rather large projects that had a visible impact on the cost of feed-in tariffs, whereas small-scale residential photovoltaics represented a lot in terms of number of projects but very little in terms of capacity. For a large part, these large projects were photovoltaic installations on the roofs of agricultural buildings. Project developers, investors, and farmers themselves had quickly seen the opportunity that these large rooftops constituted and such projects proliferated, often designed by investors who rented roofs to install photovoltaic panels on, or who offered to pay for a photovoltaics-covered building the farmers owning the land would then have full use of (Interviews 15, 24, 26, 30).

Such projects were widely disregarded: many considered them as a diversion of public support and as one of the causes for the drifting of the FIT schemes (Interviews 13, 14, 15). At any rate, they were not what the FIT scheme was initially intended to support; their proliferation was clearly an unexpected effect of feed-in tariffs. Indeed, the FIT scheme turned out to equip and constitute unexpected forms of market agencies that partially transformed its original objectives and turned it into, for instance, a tool for territorial development (cf. Chapter 5 below), a supplement to farmers' retirement pensions, or a financial opportunity. The proliferation of such market agencies is precisely what the January revision targeted via the creation of tariff categories and the reinforcement of constraints for BIPV eligibility.

1.3.2.2.2. Spring and summer 2010

Either because of its complexity, or because it was written in a rush, the administrative order had to be completed and corrected by several texts (MEEDDM, 2010b, 2010c, 2010d). A *circulaire* was published on 1st July 2010 to provide departmental prefects[125] with guidelines on the implementation of the new scheme, especially on the tricky issue of building integration (MEEDDM, 2010e).

Over a dozen pages, it detailed the technical and non-technical criteria for eligibility to BIPV and simplified BIPV tariffs. A couple of "zooms" gave examples of how to interpret some of the new dispositions, a table listed which buildings could and could not be considered "residential", "educational" or "medical". The document even included an FAQ – including photographs – to address common difficulties encountered with the BIPV label. Despite its aim to clarify the matter, the document is in fact a maze of details and exceptions.

Last, the *circulaire* created a "*Comité d'évaluation des produits photovoltaïques intégrés au bâti*" (CEIAB).[126] Constitued by representatives of the ministry for energy, the ministry for construction, the ADEME, the *Conseil Scientifique et Technique du Bâtiment* (CSTB)[127] and of up to five additional representatives of the public administration, this ad hoc committee was expected to meet on a regular basis to assess the compatibility with BIPV technical standards of the photovoltaic equipments it had been asked to review. Its dealings were purely consultative, but they were meant to provide guidance on a notion whose subtleties were getting harder and harder to follow. The ground rule was that in a BIPV system, the photovoltaic panel had to be situated in the roof plane and to be necessary to the building impermeability – but this apparently simple rule dissimulated a wealth of special cases and potential ambiguities, especially as refining the definition of BIPV was a way to target photovoltaic support.

> "Then, there were adjustments, because we realised that some things did not work. At the technical level, I think there has not been too many substantial modifications, but when it comes to uses or secondary criteria regarding buildings, the grid changed a lot each time, because of intentions such as: 'we need to put farmers out of the schemes, the building needs to be closed, not open' – this targeted the *hangar* open on all sides… The management was a little chaotic. […] In some situations such as these we felt the criteria were not perfect, but overall it works all the same." (Interview 15, DGEC)[xiii]

These efforts in directing photovoltaic support towards building-integrated photovoltaics are characteristic of the difficulty to control the effects of the FIT-PV *agencement.* They highlight the amount of resources that was necessary to frame BIPV as a specific good and, more importantly, to maintain this framing. That the definition of BIPV has so far remained imperfect and even problematic in spite of all these efforts emphasises the difficulties with disentangling a type of photovoltaic electricity generating systems which specificity lies precisely in their close entanglement with a building. It is, by definition, impossible to provide a thorough definition of BIPV, since it would imply considering all types of buildings. It is also *de facto* impossible to control all the installations declared as BIPV, as it would require too much time and workforce. Besides, as the previous quote suggests, the administration approached BIPV as a manner to encourage specific photovoltaics-centred business models over others, which complicated the operation of framing even further. Defining BIPV was not just a matter

[125] Prefects are representatives of the State at the local level.
[126] Committee for the assessment of BIPV products.
[127] The CSTB is a French public organism devoted to research and expertise in the construction sector.

of framing a product eligible for FITs, it was also about framing the market agencies that constituted acceptable suppliers in FIT-framed transactions. The arrangement of the photovoltaic system itself was thus considered as active: from the administration's perspective, it was one of the elements that constituted the market agency of photovoltaic electricity producers, and it could then be used as a proxy to determine who should have access to FITs and who should not.

1.3.2.2.3. August-September 2010

These re-adjustments of the tariff grid generated dissatisfaction and were contested in front of the *Conseil d'Etat*, especially by farmers who felt discriminated against. Nonetheless, they did not succeed in containing market growth. Following a report by Charpin et al. (2010) assessing support to photovoltaic electricity, the *Arrêté du 31 août 2010* introduced several additional modifications (MEEDDM, 2010f). Once again, it was announced several months ahead, triggering a surge in project requests in the meantime. This time, tariffs were decreased by 12% for all categories, expect for small BIPV installation on residential buildings. BIPV criteria were slightly modified. As one interviewee pointed out (Interview 16), there still was no direct way to control volumes, but this time, mechanisms for re-calibration of the scheme were embedded in FITs, which were set to decrease by 10% every year from 2012 onward.

1.4. 2011: Redefining feed-in tariffs for PV-generated electricity

1.4.1. The Moratorium of 9 December 2010

As the next section will detail, this additional decrease did not succeed in stalling the development of photovoltaics any more than previous ones had. Not knowing how to face the sustained growth of the market, the government eventually decided on a three-month moratorium from December 2010 to March 2011. A decree signed on 9 December 2010 suspended FITs for all photovoltaic projects that had not received their "financial and technical proposal for grid connection", i.e. that were not sufficiently advanced. Only small installations (i.e. inferior to 3 kWc) benefited from an exception. The explicit purpose of this temporary suspension was to buy time to reconsider photovoltaic support and redesign FITs in a more efficient, fairer way. A *concertation*[128] with stakeholders was organised to this end.

Time was limited, though, and so were options. It was not possible to change the law in only three-months. Policy-makers then had to do with the range of instruments mentioned in the 10 February 2000 Bill, that is, purchase obligations and calls for tenders. The effects of the moratorium and the *concertation* itself will be addressed in the next section; here, I focus on its outcome as far as photovoltaic support schemes are concerned.

[128] The French term "concertation" is close in meaning to the English "consultation". However, since both "consultation" and "concertation" exist in French, I have chosen to keep the original French term so as to avoid ambiguity.

The main objective of the revision, as it was expressed in the suspension decree, was to re-establish some degree of security on the government's side, that is to gain back control over the emerging photovoltaic market and its impacts in terms of electricity generation and, more crucially, collective costs. To do so, one option was to directly cap costs by setting a limit to the amount of CSPE allocated to photovoltaic support. This did not necessarily impose a strong limitation on photovoltaic development, since the mechanisms used to calculate the CSPE could be redesigned. Such was the proposal articulated by the NGO Hespul. By re-evaluating what was to be taken into account when calculating the costs of photovoltaic electricity and feed-in tariffs, Hespul argued, the government could make photovoltaic policy less expensive. Thus, simply redesigning the CSPE could provide a solution to distributional issues without shrinking the photovoltaic market too much (Hespul, 2010, 2011; interview 3).

It is likely, though, that the government considered that such a solution would only act on a symptom, and not address the roots of the problem. Reading through Ministers' declarations, press releases, interviews with civil servants and stakeholders, it becomes clear that the core issue was that FITs, as they used to be, provided no reliable means of control over the development trajectory of the market. Not only was photovoltaic support costly, its benefits were diverted from their purpose: they appeared to be reaped by Chinese photovoltaic modules manufacturers, speculators, large-scale photovoltaic developers and farmers trying to secure their pension.

1.4.2. Post-moratorium reforms

Photovoltaic support was thus redesigned with a view to control not just the volume of projects but also their nature. In this, the revision perpetuated the previous attempts to take into account the multiplicity of photovoltaics and to stop promoting all the forms of the technology indiscriminately. Contrary to the one-shot readjustments of the previous year, the scheme resulting from the moratorium and consultation was meant to be stable, predictable and lasting.

The reform was explicitly designed to support the installation of 500 MW of new photovoltaic capacity each year - no more (Senat, 2011; Interviews 3, 15, 17). This cap was deduced from the target of 5400 MW in 2020 suggested during *Grenelle de l'Environnement*[129] and confirmed in the 2009 PPI (Grenelle de l'Evironnement, 2007; MEEDDAT, 2008c, MEEDDAT, 2009c, MEEDDM, 2009c). In the new scheme, photovoltaic installations are divided into a dozen categories, each submitted to a different regime, with several categories of feed-in tariffs for small, building integrated systems and two types of calls for tenders for larger photovoltaic installations (cf. Annex 4). It is a continuation of the gradual refinement and increase in complexity that started in January 2010. Each of the twelve categories of photovoltaic installations is defined according to three criteria: capacity, situation of the installation, type of building on which the system is mounted. The list of requirements for an installation to qualify as BIPV is one and half page long, and it takes three pages of tables and high-level mathematical formulas to define the FIT calibration mechanism.

[129] The "Grenelle de l'Environnement" was an in-depth consultation of civil society on environmental policy objectives organised in 2008. It was meant to prepare two Environmental Policy bills, which were voted in 2009 and 2010.

1.4.2.1. "Self-adjusting" feed-in tariffs

Post-moratorium FITs are defined by the *Arrêté du 4 mars 2011* (MEDDTL, 2011). This *arrêté* lowers feed-in rates and restricts FITs to small-scale BIPV. The main innovation that it introduced was a mechanisms designed to allow for the "self-adjustment" of feed-in tariffs to market evolutions.

In Germany, as under the previous French system (MEEDDM, 2010f), FIT levels decrease once a year. One of the civil servants who participated in the elaboration of the new design recalls that "this seemed unrealistic, because over a year production costs have decreased by 30%, so if we adjusted after a year it was too late" (Interview 15). Having consulted grid operators to know which timeframe was acceptable to them in terms of information collection and dispatch, they decided for a quarterly basis. The tariff is thus set to decrease "automatically" every three months on the basis of cumulated purchase agreement requests for a specific category. The more projects in the waiting list, the sharper the decrease. FITs are then supposed to adjust without recourse to political management (MEDDTL, 2011).

The decrease is "automatic" insofar as the decrease factors associated with specific amount of new projected capacity are defined ahead and listed in a table. Every three-months, the CRE reviews data provided by grid operators, states which factor should be applied, and determines the tariffs for the following quarter according to the formulas provided by the administrative order. The deliberation is usually very short, since nothing is left to be negotiated (Interview 22, CRE). The new tariffs are then officially adopted through an *arrêté*.

1.4.2.2. Differentiating support according to types of photovoltaic installations

To take into account the variety of photovoltaic projects and to channel development in specific directions, FITs are differentiated. The structure of the scheme is based on a refined version of the categories developed in 2010. Three criteria are considered: the size of photovoltaic systems, their integration or not into a building and the kind of the building they are installed on. There are five tariff categories (T1, T2, T3, T4 and T5), each further divided into several subcategories. For each category, the *arrêté* defines a formula for calculating the tariff at a specific point in time; subcategories are differentiated by the value of specific factors in the equation. To complicate matters, not all categories of tariffs decrease at the same rate: small residential projects are recorded separately from the rest, and the decrease for T5 is constant and does not take into account the number of projects recorded.

T5 is indeed the "default" tariff, and was deliberately set at a very low level that could not guarantee project profitability. It applies to the types of photovoltaic projects and installations that the government wished to have more control upon: ground-mounted photovoltaics, non BIPV, and larger scale BIPV. These were the categories of projects that weighed the most in terms of (projected and actual) installed capacity and cost, and the government considered that FITs did not allow for sufficient control over their development. As a result, projects falling in the "T5" category were not supposed to be supported by FITs, but by calls for tenders, which were expected to allow for more control over their development. The calls for tenders were divided into two distinct categories: a "simplified call for tenders" ("*appel d'offres simplifié*") for installations between 100 and 250 kWc (roughly 1000 to 2500 m^2), and a standard call for tenders divided into seven lots for installations over 250 kWc.

For the first category, the main goal was to control the volume of new photovoltaic installations, hence the cost of public support: every quarter, calls for tenders are open for a specific installed capacity, and the only criteria considered is the price. Medium-sized, diffuse photovoltaic installations are difficult to control, because they have a relatively large impact in terms of installed capacity, but remain too decentralised to be effectively steered by public authorities. The "simplified call for tenders" is a tentative compromise between the will to control the development of photovoltaic generation and the practical, technical and procedural constraints posed by the administration of decentralised forms of investments. Its objective is the installation of 300 MW of photovoltaic capacity by 2014, i.e. 120 MW/year, allocated over seven periods (Cahier des charges de l'appel d'offre…, 2011). As one civil servant explains,

> "Every quarter, we open up a period in which people apply, and we pick winners only by the price they offer, which is in fact the only objective thing to base the selection upon, and let the best win. If you are not selected, you are free to apply again for the next quarter, modify your project, there's no problem. We're at the limit of the legally possible, because it is a single call for tenders, but split into several slices, it is rather odd. But we tried it, and it works rather well. […] It has one flaw: it favours the cheapest panel, so likely Chinese. But on this segment, they're small actors over which we have no political grasp, so we had no other way to encourage them to chose French panels or technologies anyway." (Interview 15)[xiv]

One crucial advantage of the calls for tenders system – besides providing control over quantities – is that it forces photovoltaic developers and prices to come out into the light and makes it possible to identify and list them, therefore giving visibility over the market:

> "I have to admit that for once – and that's the advantage of calls for tenders – […] it is transparent. It has the quality of opening things up, and the administration can chose tariffs knowingly, and we have access to a market price at a time t. That's very important, because even for us at SER, it is complicated to estimated, to trust our members on the estimation of a tariff, of the fair tariff." (Interview 16, photovoltaic sector representative)[xv]

The second call for tenders is targeted at large-scale projects, either on buildings or ground-mounted. It is meant to provide for 450 MW by 2014, i.e. 180 MW per year between July 2011 and 2014. It was designed to allow for the steering of the development of photovoltaics in specific directions and to promote the emergence of innovative "*filières"* by introducing qualitative criteria. It is divided into seven lots targeted at three categories of photovoltaic technologies: building-mounted, innovative technologies for ground-mounted photovoltaics, and mature technologies. These categories were specifically designed to direct support towards technologies that were deemed promising (such as concentration or tracker modules) or that could promote French industries and/or know-how (Cahier des charges de l'appel d'offres …, 2011). A civil servant recalls:

"I think that was a victory for the DGEC […]: we managed to split the call for tenders into several weird categories – well, categories that people thought weird – that make it possible to target specific technologies that we thought were promising, on which French actors are working. But that was a hard fight […– We managed to find a solution, I think something that holds, that cannot necessarily be reproduced every year but that at least enabled these firms to realise their first projects. Otherwise, they would never have had this opportunity. And then, it's up to them to export their product." (Interview 15)[xvi]

1.4.3. Design issues

1.4.3.1. A shrinking market

However, the new support scheme did not entirely solve the problem of calibration and adjustment, and, as the next section will show, it has been contested by many market actors. Its focus on the control of market deployment indeed largely leaves out the "incentive" dimension of the instrument. FIT schemes work insofar as they enable actors to constitute photovoltaics as an opportunity. The 2011 FIT scheme guarantees security on the government's side by providing for the control of policy costs, but takes little account of the needs and specificities of market agencies. In other words, it is designed to control and steer the market, but not to sustain it.

First, the 500 MW/year cap on new installations forces the photovoltaic market to shrink. It defines the size of the market on the basis of objectives that pre-date its deployment, thereby ignoring the actual capacity set up by the emerging photovoltaic sector; and, as a static objective, it locks it on a constant growth pathway and thus opens limited perspectives. These constraints on market deployment materialise in the steep decreases in feed-in rates, which, according to one industry representative, was based on an indicator that artificially accelerated it for specific market segments, because it did not take into account all the steps through which a photovoltaic project must go.

"For residential photovoltaics, the grid-connection request more or less corresponds to a project that is going to be carried out in 95% of the cases. When you have a grid-connection request, the project happens; the failure rate is very small, because it is smaller, the investments are less important, it is safer… In contrast, for larger projects, you face quite a few issues, especially the issue of finance. […] So the decrease indicator is not adapted. What should have been used were signed PTF with a paid deposit: when you sign your PTF and pay the deposit, then you can say that your project has gone far enough to be considered serious and carried out." (Interview 16)[xvii]

Then, except for small residential photovoltaics, which remained unproblematic, tariff decreases were extremely steep and rapid. The government had deliberately opted for very drastic reductions (Interview 15), and for the first quarters the decrease was systematically of 9.5% (the maximal possible factor). One interviewee stressed that it was not sustainable, since "[he had] never heard of a sector in which costs are reduced by 10% every quarter! It does not exist" (Interview 16).[xviii] It soon led to a situation in which, according to representatives of the sector, it was not possible to carry out any projects, and all the requests had to be "from isolated actors or people speculating on a cost decrease" (Interview 16). By the summer of 2012, the sector was already calling for some form of emergency measures that would send a positive signal to market actors (Interview 16, 18, 36, 37).

Indeed, on top of limiting its prospects, the 2011 support scheme did nothing to revive a sector that had been severely damaged by the moratorium. The government hardly took any account of the effects of the moratorium itself, and seemed to assume that the photovoltaic sector was still some sort of proliferating, untameable, speculating mass – even though the moratorium had considerably cleared the picture and reduced the confidence and resources of those that survived it. Even for small-scale residential photovoltaics, which remained profitable, there was a decrease in activity (Interview 3). Maintaining a photovoltaic market indeed implies maintaining photovoltaic market agents, and the new scheme did little to re-stimulate their interest (Interview 37). The simplified call for tenders, for instance, failed to fulfil its objectives: for the first period, awarded in the summer of 2012, the projects that applied accounted for only 68 MW over the 120 MW targeted, and no more than 45 MW were selected (Interview 16). Yet, the mean price offered by project developers was 23 c/kWc – quite a leap from the 17.5 c/kWh that large simplified BIPV projects (in theory more expensive) had to live by in July 2012.

1.4.3.2. Challenged categories

Problems with the new support scheme were not limited to the level and calibration of support, but were also related to the categories of photovoltaic products that it framed. BIPV and photovoltaic installations falling under the "T5" tariff category proved particularly difficult to pacify.

Following the recourses that were made in 2010, the *Conseil d'Etat* challenged he framing of photovoltaic installations in 2012. Several recourses had been made about the many tariff revisions that had occurred since early 2010, which led the *Conseil d'Etat* to examine the texts in their entirety. In two decisions, it stated, first, that the distinction according to the use of buildings introduced in January 2010 was illegal, and, second, that the CEIAB had no legal existence (Conseil d'Etat, 2012a, 2012b). In short, difficulties in steering the FIT scheme did not arise only from an overflowing market activity, but also from a lack of institutional equipment: the legal tools that would have helped readjust incentives were not stabilised. Public authorities had to design *ad hoc* mechanisms that the *Conseil d'Etat* dismissed for not fitting within the existing legal framework. Great uncertainty over some of the tariff categories ensued (Interview 16). As a result of these decisions, the lists of "approved BIPV material" that the CEIAB had published also had to be put offline until its status was clarified (and they have remained so to this day), resulting in uncertainty regarding the exact definition of BIPV equipment.

Besides, by the fall of 2012, the default tariff ("T5"), which had been designed precisely not to be used, started to trigger interest from specific market actors (Interview 23). Some project developers applied for the tariff instead of going through the call for tenders procedures, betting on business plans that made such choice profitable. This unintended event suggested that the scheme was not so well calibrated, and at any rate not able to prevent overflows, and that the automatic decrease was not enough to keep track of market evolutions. The FAQ from the MEDDE (Ministère de l'écologie, du développement durable et de l'énergie) website section on photovoltaics outlines this unexpected development:

> "The T5 tariff, created in March 2011, was not supposed to be used since call for tenders system were put in place, allowing for a better steering of technologies and better accounting of associated environmental issues. However, as a result of the decrease of photovoltaic modules market costs (particularly because of an important global overcapacity), the T5 tariff has become profitable enough for projects using low-cost equipments and workforce, and creating little or no added value in France. This triggered a very significant growth of the volume of this type of projects in the grid connection waiting list over the last few months."[130]

In addition, the efficiency of the scheme, in terms of installed capacity and of cost, was contested in several reports by public institutions (Cour des Comptes, 2013; Dambrine et al., 2012).

1.4.3.3. Adjusting yet again

After the election of François Hollande and the subsequent change of government in May 2012, lobbying from representatives of the photovoltaic sector, the need to clarify legal issues pointed out by the *Conseil d'Etat*, and market evolutions led the government to partially amend the system. Revisions were announced in October 2012 by Environment Minister Delphine Batho, and were formalised by two administrative orders in January 2013 (MEDDE, 2013a, 2013b). Some of the measures announced were to take effect immediately.

The first decision was to increase ambition: the target of 500 MW new capacity per year was doubled. Support thus had to be recalibrated to provide for 1000 MW each year. As a result, the tariff adjustment grid was revised so as to slow down the decrease and allow for more projects to be developed every quarter. Besides, tariff decrease was capped and cannot exceed 20% a year.

The FIT structure was simplified to take into account the decision of the *Conseil d'Etat*. The tariffs "T2" and "T3" that discriminated between buildings according to their use were suppressed, and BIPV tariffs were maintained only for installations smaller than 9 kWc. The "T5" tariff, that had turned out to be used when it should not have been, was decreased by 2c/kWc (i.e. almost by 20%).

Last, the Minister announced a measure that had been considered for almost two years, and which aimed at helping the French photovoltaic module industry – who had been hit hard by recent changes: photovoltaic projects could benefit from a 5 to 10% premium if they used equipment produced within the EU.[131]

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[130] "Le tarif T5, instauré en mars 2011, avait vocation à ne plus être utilisé depuis la mise en place des systèmes d'appels d'offres, qui permettent de mieux piloter les technologies et de mieux prendre en compte les enjeux environnementaux associés. Or, suite à la baisse des prix de marché pour les modules photovoltaïques (notamment à cause d'une surcapacité mondiale importante), le tarif T5 est devenu suffisamment rentable pour des projets utilisant des équipements et de la main d'œuvre à bas coût, ne créant que peu ou pas de valeur ajoutée en France. Cela a entrainé une hausse très significative du volume de projets de ce type en file d'attente de raccordement lors des derniers mois."

[131] This measure was recently judged non conform to EU market rules and cancelled in May 2014.

However, the national debate on the energy transition, launched in 2012, delayed more substantial modifications, and in particular the clarification of medium to long-term objectives for the deployment of photovoltaics in France. In this context, the punctual revisions that allowed photovoltaic support scheme to stay standing did not address the sources of the difficulties it faced and were not enough to spark market interests anew. As one interviewee from a photovoltaic sector firm related:

> " The debate on the energy transition prolongs this period of uncertainty, because, as of now – and this s understandable, we can accept that – the government cannot take strong policy measures, since it relies on the outcome of the debate to prepare a bill […] that will determine the orientation of French energy investments for the […] next fifteen years. […] So, as long as this debate goes on, as long as a conclusion is not reached and the government does not really express what it wants to do on the basis of the outcome of this debate, we have to wait, which is terrible because the sector cannot afford to wait. This has been told, this has been heeded, they have taken a few measures, really minor ones, but these did not have the required effect – but we knew this much already […]. We are waiting, and this is terrible, especially since the level of activity is very low, too low for many firms to last very long. We really have a reprieve, many of us have. And this is terrible because we do not know where it will lead to. Even though the government and the president have announced objectives, we can see now that these objectives could be broken." (Interview 36, enterprise)[xix]

Section 2 – French photovoltaics in crisis

The emergence of photovoltaics in France as a source of electricity, a market and a political issue occurred between 2008 and 2011, which justifies a closer focus on this period. As the evolution of regulations and policies that the previous section traced back suggests, it corresponds to a moment when feed-in tariffs for PV-generated electricity became active, and to an extent too active for their effects to be monitored. This section focuses on how the "over-activity" triggered by feed-in tariffs unfolded and on its consequences by retracing two successive mobilisations around the FIT-PV *agencement*. First, feed-in tariffs as market *agencements* sparked a proliferating and unbridled economic activity by providing an extremely proofitable outlet for any type of grid-connected photovoltaic installations. This overflowing market activity turned the development of photovoltaics into a matter of concern and a political issue. The crisis peaked between December 2010 and March 2011, when the moratorium on FITs and the *concertation* on photovoltaic policy mobilised a disorderly public concerned by photovoltaic support and actualised FITs as political *agencements*.

2.1. Overflows

2.1.1. Photovoltaics from the margins into the spotlights

The emergence of photovoltaics in France was driven by the 2006 FIT scheme: it was only with the doubling of FITs and the creation of a premium for building-integrated photovoltaics (BIPV) in July 2006 that grid-connected photovoltaic installations in France could be made profitable (Ministère de l'économie, des finances et de l'industrie, 2006a). As outlined in the previous section, the 2006 FIT reform did not just raise the level of support provided by FITs; it also suppressed the mechanisms designed to take into account the dynamic effects of FITs in the previous scheme. The 2006 FIT *agencement* itself considered photovoltaic electricity as a uniform, pacified and unproblematic good, as much as it considered photovoltaic electricity suppliers as already framed, predictable agents. The only tool available to take into account the concrete dimension of photovoltaic electricity generation was the BIPV premium, but the definition of BIPV itself remained too loose to constitute a proper framing. Thus, because it qualified neither of them in any details, the FIT scheme provided no means to control the activities it triggered.

This probably owes to the fact that feed-in tariffs for PV-generated electricity were *not* intended to trigger much activity. Support to photovoltaic electricity was a marginal policy, not expected to disrupt the French electricity system in any way. At the time, the government considered photovoltaics as very expensive technology in the early stages of their emergence, and their development was not expected to have any significant impact in the short to medium term. This is made very clear in the Report on the *Programmation Pluriannuelles des Investissements de Production Electrique* (PPI) for 2005-2015 (Ministère de l'économie, des finances et de l'industrie, 2006b).[132] The scenarios used for the PPI, taking into account the announced increase in FITs, assumed that cumulative installed photovoltaic capacity would reach 120 MW in 2010 and 490 MW in 2015, with the bulk of capacity installed in overseas territories and non-interconnected zones (ZNI). The report projected that it would lead to an estimated photovoltaic electricity generation of less than 1 TWh in 2015, most of it being generated in zones not connected to the central grid. Under such hypotheses, it stated in bold letters that "*it can then be concluded that solar photovoltaic generation will not contribute in a significant way to the balance of supply and demand in continental France by 2015*" (Ministère de l'économie, des finances et de l'industrie, 2006b, p. 48). [xx]

The support scheme was clearly not aimed at the mass development of grid-connected photovoltaic capacity. Instead, the deployment of photovoltaic electricity generation was directly targeted at insulated systems in overseas territories and Corsica. This orientation is explicit in the design of FITs, which are set at a higher level for these territories - a distinction that was not justified in strictly economic terms, as the CRE pointed out, warning that it would induce an unnecessarily high profitability in these regions.

> "In Corsica, in overseas *départements* and in Mayotte, in any of the cases considered, for a firm, the tariff yields very high profitability. With the same tariff as in continental France, the increase in resource alone could compensate a 20% increase in equipment costs. It is thus not necessary to raise the tariff in comparison to that applicable on the continent. Indeed, while the current tariff is approximately equal as the new tariff proposed for continental France, the observed development of PV in these zones demonstrates the useless character of the proposed raise." (Commission de Régulation de l'Energie, 2006, p. 7)[xxi]

The objective in the 2006 PPI, as stated in the 7 July 2006 *arrêté*, was to reach 160 MW of installed photovoltaic capacity by 2010, and 500 MW by 2015 (Ministère de l'économie, des finances et de l'industrie, 2006b). Ambitions for the deployment of

[132] Programmation Pluriannuelle des Investissements de Production Electrique 2005-2015, June 2006.

photovoltaic electricity thus remained modest, and so did the means allocated to the policy.

Between 2007 and 2009, photovoltaics shifted from this marginal position to a more central one as political focus on environmental and climate issues increased at the national and European levels. These were rather intensive years in terms of renewable energy legislation and policies. At the EU level, negotiations on the European Energy-Climate Package began in March 2007 and resulted in the adoption of a set of climate and energy related Directives in December 2008, including binding renewable energy development targets for Member States (Commission of the European Communities, 2007b, 2007c, 2007d; European Parliament and Council, 2009). Concomitantly, in France, the creation of a Ministry in charge of both Energy and Ecology in 2007, and the *Grenelle de l'Environnement* process, which started in 2007 and led to the adoption of two laws in 2009 and 2010, made environmental issues a policy priority and spurred the development of renewable energy policy in France (MEEDDAT, 2008c).

Ambition increased accordingly. The objective for the share of renewable energy in final energy consumption in France was set at 23% in 2020, in line with the target adopted at the EU level. For photovoltaic electricity, it translated into a target of 5,400 MW installed capacity by 2020 – a sharp increase from the former objective of 500 MW by 2015. Indeed, the 2006 objectives had become obsolete: "the number of authorisations in the solar photovoltaic sector is taking off, with nearly 1,600 MW authorised: the objective set for 2015 by the previous PPI is already outreached." (MEEDDAT, 2009c, p. 28). These new commitments were confirmed in the PPI for 2009-2020 (MEEDDAT, 2009c) and in the *Plan d'action national en faveur des énergies renouvelables* (MEEDDM, 2009c).

Photovoltaics were still considered marginal but, as in the Cochet Report a few years earlier, they were put forward as promising technologies bound to gain research and industrial importance. Staying in the race was crucial:

> "France's ambition is to play a leading role at the global level in the upcoming technological revolution. To this end, it is necessary to give strong impetus to the French market, to speed up research and to build up a real solar industry in France." (MEEDDAT, 2008, p. 18) [xxii]

In this logic, FITs were a way to develop a market that could allow for the emergence of an industry and encourage R&D. As high-tech products, photovoltaics became the figurehead for renewable energy policy, even more so that the fulfilment of their great potentials still seemed relatively remote.[133] Their costs remained high, and no one could foresee their upcoming drop. For instance, in the 2008 Plan for Renewable Energy Development it is not considered necessary to revise FITs levels before 2012:

> "In order to provide investors with long-term visibility, it is already announced that tariffs will be kept at [their current] levels at least until 2012" (MEEDDAT 2008, p. 22).

133 For instance, in the 2008 Plan for Renewable Energy Development it is not considered necessary to revise FITs levels before 2012 : "In order to provide investors with long-term visibility, it is already announced that tariffs will be kept at [their current] levels at least until 2012." (MEEDDAT 2008, p. 22, author's translation)

To quote an interviewee, since “people knew that photovoltaics were extremely expensive”, support for the development of photovoltaic electricity “was more of a tool to promote all renewable energy”, and as such was “merely symbolic” (Interview 16).[xxiii]

2.1.2. Market changes

At the same time, photovoltaic markets underwent radical changes. The price of photovoltaic modules had remained stable between 2004 and mid-2008 because a shortage of polysilicon constrained production, while German and Spanish incentives made it possible to buy the technology at high prices. Driven by the expansion of polysilicon production and downstream manufacturers, it sharply fell from $4.00/W in 2008 to $2.00/W in 2009 (Bazilian et al., 2013). Photovoltaic modules prices have kept decreasing since then and were falling by around 20% a year between 2009 and 2011 (Solarserver, 2013). The global dynamics of the photovoltaic modules market, which had not been taken into account when designing FITs, suddenly entered the scene.

As incentives remained high, return rates for photovoltaic projects in French went flying through the roof. By 2009, FITs amounted to over 60 c€/kWh for BIPV, and their combination with additional support instruments, including a 50% tax rebate on photovoltaic installations for individual houses, made French incentives for photovoltaic electricity generation the most attractive in Europe. Lifted by a growing number of subvention-fuelled project developers, the market swelled out of proportions. The generosity of incentives allowed new actors to enter the market and a wide variety of business models to develop: large-scale ground-mounted solar plants, rental of the roofs of farm buildings for photovoltaic installation, BIPV on large public buildings, installations on individual houses, etc… With rates of returns of up to 25%, photovoltaic electricity had turned into a financial product and an extremely profitable and secure investment.

> “So, these people were used to an increasing windfall, and they were visiting households saying, ‘you’re not going to put your money at the *Caisse d’Epargne* when by just putting a panel on your roof, you’ll get nearly the same risk rate (it may break, and still, I’ll give you an insurance), and instead of earning 4% you’ll earn 15%’. Well, I said 15, but there were household projects in sunny regions at the time that according the Charpin Report, could go up to 25%. So people lived on, they were doped to subvention.” (Interview 17, utility)[xxiv]
>
> “[Boasting about having the highest tariffs in the world] was telling investors, ‘come, you’ll make plenty of money, you’ll have Internal Rates of Return (IRR) of 20-25%’. That was the reality of it! The 55, even 60 eurocents tariff plus the 50% fiscal credit, we have always denounced it. It was madness. With the 5.5% VAT on top of it… and when individuals brag about having return times of 5 years, with 20-years contracts… That was nonsense.” (Interview 3, NGO)[xxv]
>
> “When you have IRR of over 10%, and sometimes of 20, 30% or more, it cascades down. The worst I have seen were financial vehicles in ISF-TEPA, that set up sales and installation cabinets, that invested in sales and installation societies for private households, who in turn benefitted from the fiscal credit on the system, with on top of that a high FIT. At some point, we had the most subsidised photovoltaics in the world. This is not virtuous for economic actors because they make no efforts. It opens the door to all the clowns that go ‘oh my god, we are turning photons into gold! I need to rake it in, I need to get some!’” (Interview 18, representative of the photovoltaic sector)[xxvi]

The "symbolic" tariff turned out to be very active and to have unexpected but very concrete, immediate effects.

> "I think that with photovoltaics, they thought it was a gadget, 'let's set a high tariff, that will be a political display'. Except after a while… During the first six months, nothing happened, and then all of a sudden there was a surge. I think they had not realised that at some point all installers were going to do photovoltaics, people were going to get out of control, and of course they add a stupendous tariff, a 50%% fiscal rebate… So people sold financial investments, there was very little renewable energy motivation in there… 90% of the motivation of those who turned towards photovoltaics was financial: 'I make an attractive financial investment, my tariff is guaranteed for 20 years, I more or less know my sun.' On top of that, you add for residential installers that were at best ill-trained, at worst dishonest, and you get a bedlam. But I don't think that public authorities were aware that it would be such a huge success; the tariff was probably drafted on the back of an envelope." (Interview 5, ADEME)[xxvii]

Though the increase in newly connected installations remained reasonable in 2008 and 2009, the number of purchase agreement requests rose exponentially:

> "It started increasing in 2008-2009, because at this time, well, costs decrease, markets open, all over the world, and so the machine starts running full speed, and then into over-drive." (Interview 16, representative of the photovoltaic sector)[xxviii]

As Fig. 11 shows, they translated into connected power in 2010 and 2011. High FITs were secured with no guarantee on the future of projects, while installations costs decreased extremely fast, feeding a bubble soon described as "speculative". This fed a bulging waiting list of virtual projects but actual contracts that lengthened too fast for grid operators and administrations to keep up and threatened to weigh heavy on future electricity bills (Fig. 12).

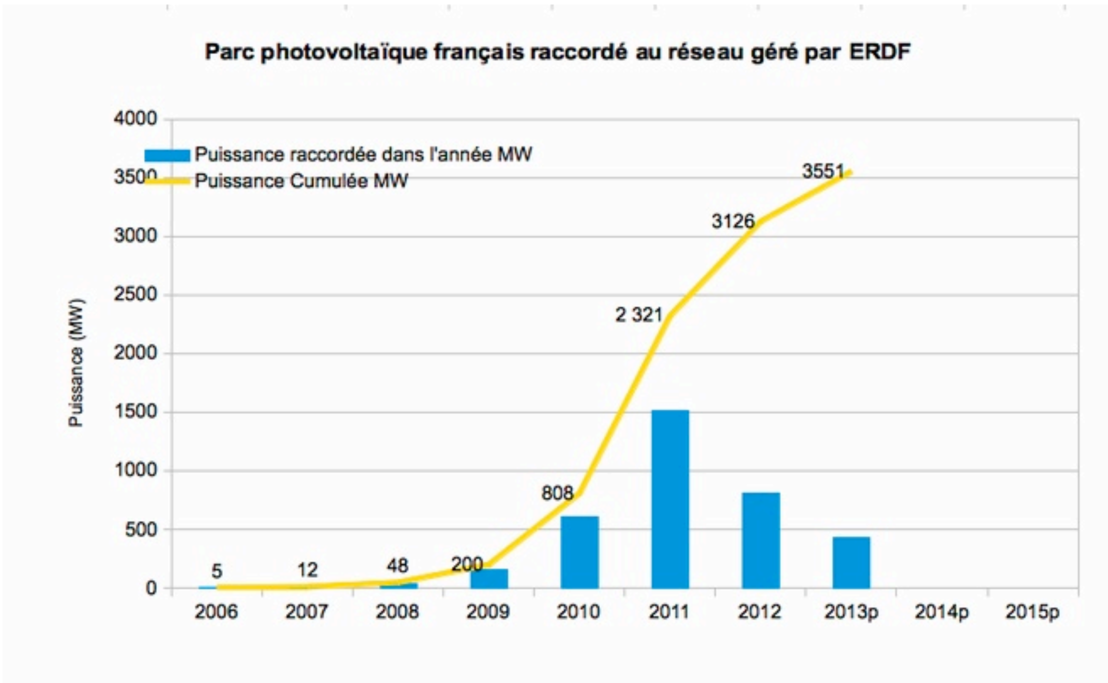

Figure 11 The evolution of grid-connected photovoltaic capacity in France (newly installed and cumulated), 2006-2013. Graph retrieved from photovoltaique.info

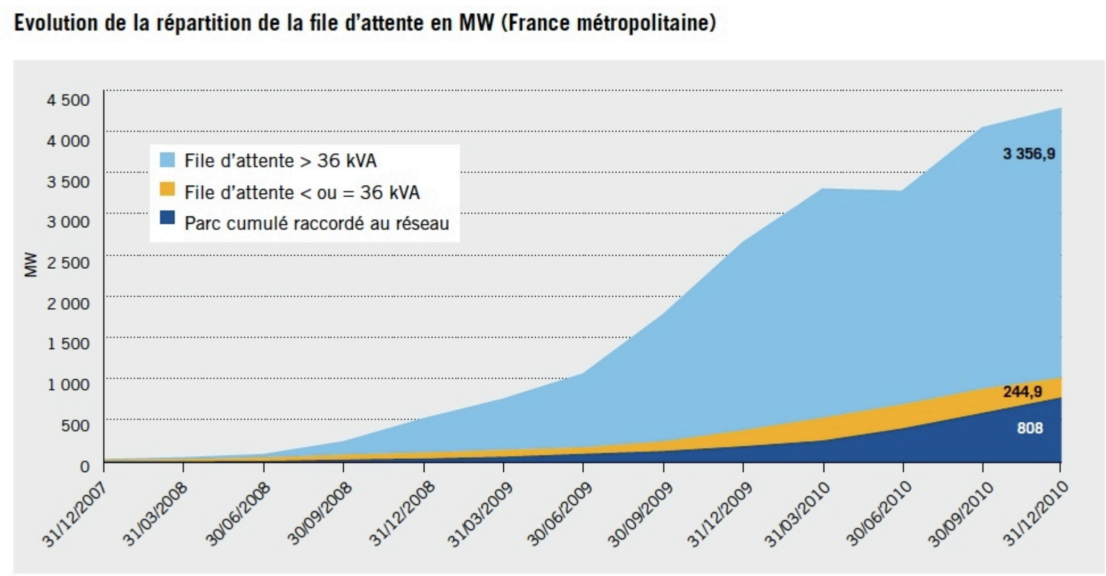

Figure 12 Evolution of the "waiting list" for grid connection in metropolitan France for installations < 36 kVA and > 36 kVA, and evolution of total grid-connected photovoltaic capacity (SER, 2011)

2.1.3. MisFITs

In the face of this swelling market, first concerns about the mismatch of incentives arose in 2009. The brutal collapse of the photovoltaic market in Spain after the suppression of incentives in 2008 was a first warning sign that Member of Parliament Serge Poignant insisted on in his 2009 report on photovoltaics (Poignant, 2009; Interview 18, representative of the photovoltaic sector). EDF forwarded information from the grid operators to public authorities, warning about increasing monthly flows that were hard to manage, and about the looming increase in the CSPE.

> "We told public authorities in late 2009: 'the monthly flows that we see coming at [the electricity distributor level] seem worrisome to us. First, ERDF will not be able to meet the delays, because they cannot event recruit people at the necessary pace; besides, you will not see it in this year's CSPE, but you will see it in the CSPE 2 to 3 years from now, and you will see it for 20 years." (Interview 17, utility)[xxix]

For those directly dealing with purchase agreements and grid connection requests, the effects of the FIT were indeed literally overwhelming. EDF-AOA, in charge of all the procedures related to the purchase of photovoltaic electricity, grew at the same pace as a start-up, with its staff increasing from 8 to 100 people between July 2008 and March 2012 (Interview 35, utility) and yet could barely keep up with the amount of work engendered by market growth. As someone from EDF-AOA remembers,

> "Packs of mail arrived by dozens… Can you imagine, we received over 50 000 requests for purchase agreements in a month. In December. That was colossal. We worked day and night at the time. That was… That was really colossal." (Interview 35, utility)[xxx]

The situation was similar in the DREAL [the regional administrations in charge of the environment], who were in charge of delivering the *Certificats ouvrant droits à* *l'obligation d'achat* (CODOA) necessary for the access to FITs until mid-2010. For instance, in the DREAL Midi-Pyrénées,

> "To give you a few figures, when I arrived here in 2008, we delivered 100 [*Certificats ouvrant droit à l'obligation d'achat*]. I arrived on September, 1st, 2008. In October-November 2008, we were starting to do 100 a month, instead of 100 a year. And the last year we had to do any, it must have been January 2010, we were doing *1000 a month*. […] When I arrived, the machine was starting to be paralysed. That is, we are supposed to have two months to process these certificates. We were laboriously at two months, with an extremely negative effect: files arrived, piled up, there were two persons to process them, and when someone called to know where their certificate was at, the time we needed to find the certificate in the piles, well, that was time during which we were not processing any certificate…" (Interview 23, regional administration)[xxxi]

However, it took a while for the evidence of this overwhelming growth to reach the government. EDF-AOA alerted the DGEC in 2009:

> "I had informal discussions with [the DGEC staff], they came to see us in Lyon in December 2009. We had to beg them to come. We told them: but don't you realise! Something must be done, look! Well, the goal was that they see there were files everywhere and that we could not keep up." (Interview 35, utility)[xxxii]

The staff in charge of managing PV support at the ministerial level was limited to a few young civil servants (Interviews 18, 35, 37), and the statistical apparatus that could provide an accurate picture of the expanding market was still lacking. As an interviewee remarked, the photovoltaic sector developed at the intersection of several existing economic sectors and comprised such a diversity of (at least in part) non-conventional market actors that it did not fit in the existing statistical frame.

> "I would explain a large part of the difficulties with photovoltaics by the fact that it developed on the margin of traditional industrial branches, and that information, especially information about the number of installers as well as all the sectoral data, were not transmitted to the government, so the government did not see the inflation of the sector. […] This increase [in the number of photovoltaic installers] was not noticed by usual institutions of the building sector. So the State did not get the information […]. The turnover was completely diluted… it was still too small for the banking sector to organise and transmit information of the amount of funding. If you like, this sudden rise of photovoltaics between 2007 and 2010 happened on the margins. Entirely on the margins. And I think this has a lot to do with the nature of installers, who do not correspond to the usual profile of building actors. We had a rather impressive number of MSc up on the roofs. And these people do not usually think "syndicate" or "representation". They are not used to take membership in a professional syndicate.
> […] The problem was the lag in the transmission of information to the ministry. When you're facing a sector in which production costs are divided by two every three years… In ministries – I can see it now, in the national debate [on the energy transition], we work with statistics from 2011 for the most part. So I you like, the delay was such that… It was like having a cripple drive a Ferrari." (Interview 37, NGO)[xxxiii]

Eventually, information reached the DGEC, and its staff sent several notes to the Minister of the Ecology in 2009, warning that "there began to be too many projects compared to objectives, that all of this was pretty expensive, and that is was not logical for tariffs to keep rising when manufacturing costs decreased" (Interview 15 DGEC; Cour des Comptes, 2013).[xxxiv]

As described in the previous section, as the government began to take notice of the pace of market growth and attempted to slow things down, regulatory proliferation added to the proliferation of photovoltaic projects, each reinforcing the other. The fiscal credit for private households was decreased in January, and two targeted FITs decreases affecting specific categories of projects came into effect first in January, then in August (MEEDDM, 2010a, 2010f). Those proved rather ineffective in stalling the rising trend: as they were publicly announced a few months ahead, they only incited developers to rush for the high FITs while they were still available (Interview 3).

On top of that, the government released a large number of circulars and notes aiming at clarifying the increasingly refined – and so increasingly confusing – picture of PV incentives. This only made things even more tangled, adding layer upon layer of regulatory bodies, texts, categories and guidelines that never quite managed to thwart the multiplication of projects. “Since the beginning of the year, the State has emitted twelve circulars, orders or notes, not including the decrease of FITs and fiscal credits”,[134] as Member of Parliament Catherine Quéré recalled during a parliamentary meeting in December 2012 (Assemblée Nationale, 2010c).

In 2010, the impacts of the overflowings of the photovoltaic market became even more manifest, raising concern. “Simple calculations” showed the impact FITs would have on the electricity bill, and the Ministry of the Economy started to push for a moratorium (Interviews 12, 15, administration). In the last trimester of 2010, a report was published on the photovoltaic sector, advising FIT reductions (Charpin et al., 2010). Series of auditions were held by the Assemblée Nationale in the fall, and the government’s management of photovoltaics was strongly criticised (Assemblée Nationale, 2010a, 2010b). The issue was moving up the agenda, but not quickly enough:

> “A working group was supposed to be constituted during the autumn, for many reasons it did not happen. We got a bit late, and within three months…!” (Interview 4, Member of Parliament)[xxxv]

Viewed from within the ministry’s walls, too,

> “all this quite agitated phrase, let’s say beginning in July, August, September, October, and then the moratorium in December… […] it was not a crisis, but it all happened in a certain urgency. If only because every day, we had made calculations, projects were released that represented a few millions euros and that were going to impact the electricity bill.” (Interview 15, DGEC)[xxxvi]

Still, Jean-Louis Borloo, Minister for Ecology, Energy, Sustainable Development and the Sea, dismissed alarms. As he argued in front of a parliamentary committee:

> “The troubles encountered are at the margins. […] Developing the photovoltaic sector by 500% was the only way to meet our objectives. The fact that we reduced part of the tariffs by 12% does not mean that we are not controlling growth.” (Assemblée Nationale, 2010a)[xxxvii]

In his view, the tariff was playing its part in being “overflowed by design”: its role was to activate a process of fast market development and extension, and it was succeeding in doing so; the overflows and subsequent reframings were normal – and necessary – steps in the process of deploying renewable energy. The reform of August 2010 (MEEDDM, 2010f), which incorporated an annual decrease in FITs, was an attempt to adjust the scheme to its effects, but it did not get the chance to be put to the test.

[134] “Depuis le début de l’année, l’État a émis douze circulaires, arrêtés ou notes, sans compter la baisse du tarif de rachat et du crédit d’impôt.”

The Ministry of Finance and the Economy did not agree with its Ecology and Energy counterpart, and in the face of rising costs, started pushing for a moratorium in the autumn of 2010, but Borloo stayed firm (Interview 12, DGT). However, Borloo's position, which hinged on the commitment to develop renewable energy as a priority, was losing ground. When he left the government in November 2010 to be replaced by Nathalie Kosciuzko-Morizet, the impact of feed-in tariffs for PV-generated electricity on the electricity bill became the core issue, especially as elections drew near – electricity prices are a particularly sensitive matter in France, where cheap electricity is considered a key national asset (Interview 17; Cour des Comptes, 2013).

> "In January, I think the cabinets had not taken the measure of what it would represent on the bill, in spite of all the notes that we could send them. Borloo had made photovoltaics his showcase. […] Or if he realised, he thought that the benefits in terms of public image he got from it were sufficient to keep on. In August, he curbed things a little bit, but it still remained high. We really had to wait for the change in Government composition and the arrival of NKM for things to… Then, suddenly, people got much more receptive to the argument: 'oh my God but this is costing billions and this is going to increase the electricity bill, elections are getting closer, this is going to be a problem.' " (Interview 15, DGEC)[xxxviii]

Actors of the photovoltaic then "saw that [their] arbitrages no longer took place at the [Ministry of] Ecology but [at the Ministry of the Economy], after the crisis […]; and later at the Prime Minister's cabinet, but in no way at the Ministry of Ecology. It was: we're changing strategies, how much does it cost?" (Interview 16, representative of the photovoltaic sector).[xxxix]

2.1.4. The Moratorium: "a thunderbolt in a summer sky"[135]

The reply soon turned out to be "too much". The issue moved to the Prime Ministerial level, where drastic action was taken. On 2 December 2010, a press release from the Prime Minister's office announced an imminent moratorium on FITs "to put an end to the creation of a real speculative bubble", and the organisation of a *concertation* with stakeholders to find a new balance that would respect "the objective of 500 MW of new photovoltaic capacity each year, and protect consumers by allowing for the control of the evolution of the price of electricity" (Premier Ministre, 2010).

According to an interviewee, the government was "really extremely worried. […] We were not that far from an electoral period, and the State was very scared, and the State was very stiff",[xl] hence the brutality and stringency of the measures taken (Interview 17, utility). Because of its "panic", the government opted for the solution that provided the least uncertainty on the evolution of purchase agreements and most room for manoeuvre on its side. It momentarily took back control over the volume of projected installations, affirming its will to bridle volumes instead of meddling with prices in the hope it would suffice.

> "[The moratorium] was juridically more robust, because it was a decree, and it was a possibility provided by the law. It left time to listen to people afterwards. And it left us with much more latitude regarding the transition actually, to define clearly what would

[135] Interview 17

fall under the moratorium and what would not. And the decree could be taken in three, four days, so it was also quicker." (Interview 15, DGEC)[xli]

This was a shock for the photovoltaic sector, which did not expect its glorious summer to be ended so abruptly. Projects flowed in one last rush for FITs, and intense "stupefaction and anxiety" immediately followed (Interview 17, utility). The government's panic transferred to the sector. A threat on the very existence of many actors of the emerging photovoltaic industry, the decision was widely perceived as a death sentence for the solar sector (Interviews; Assemblée Nationale, 2010c).

> "For it is violent, today it means firms laying workers off." (Interview 3, NGO)[xlii]
> "The problem with such an action is that you do not only drastically reduce volumes, […] but it causes havoc, and it impacts the core of actors, and not only new actors… not only the promoters, in a word." (Interview 16, representative of the photovoltaic sector)[xliii]
> "… and the shock, the fact that for all these very small firms, their very existence was at stake. That was undeniable, I mean, even we argue against stop&go." (Interview 17, utility)[xliv]
> "Stopping everything is simply sanctioning the death of the small firms that cannot wait three months!" (Yves Cochet, Member of Parliament, in Assemblée Nationale, 2010c)[xlv]
> "The moratorium is going to kill the Small and Medium Businesses and the Medium Size Businesses!" (Yann Maus, CEO of Fonroche, in Assemblée Nationale, 2010c)[xlvi]
> "You are killing them today, and there will be no one left on the market but EDF and the former GDF – in short, a solution à la française." (Claude Belot, Member of Parliament, in Poniatowski, 2011)[xlvii]
> "Professionals are being killed." (Marc Daunis, Member of Parliament, in Assemblée Nationale, 2010c)[xlviii]
> "The announcement of the moratorium weighs heavily on the backlog that we patiently constituted in the wake of the shift in the market, in 2008." (Vincent Bes, Manager of Photowatt, in Assemblée Nationale, 2010c)[xlix]
> "The 9 December decree annihilates two years of work. […] It is unacceptable that decisions taken urgently can undermine so much work!" (Yann Maus, CEO of Fonroche, in Assemblée Nationale, 2010c)[l]
> "It will be the death of our industry and of all future ambitions." (AIPF, 2010)[li]
> "The moratorium is without a doubt the worst of solutions, the most catastrophic in terms of visibility – and the banks no longer want to give on loan." (Catherine Coutelle, Member of Parliament, in Assemblée Nationale, 2010c)[lii]
> "We do not want to die." "The sector is dying and not a single SMB will survive." (Touche pas à mon panneau solaire, 2010)[liii]

Despite the tension it triggered, the moratorium was a way to buy time from the relentless dynamic of the deployment of photovoltaic electricity generation, and to cut short to the proliferation of projects, stakeholders and regulations that were making photovoltaics un-manageable. As a recognition that the framework called for at least partial redesign and that the consequences of FITs had to be attended to, the moratorium opened a window for renegotiating a support scheme that the pace of market development left no time to reconsider. By temporarily freezing the FIT market *agencement*, it launched a process to re-examine feed-in tariffs as political *agencements* and to attempt to channel them back into Barry's politics. The window was however a small one, as one of the organisers of the *concertation* remembers:

> "Three months is a relatively short time in the administration, we do not have time to change the world. In particular, our analysis was: if we want to change the FIT system in depth, we will be in trouble, because we would have to change the law. […] If we wanted to do something in-between, we did not have time, because we had to modify the law,

> decrees in the *Conseil d'Etat*, a nightmare. So, when we saw that we had relatively narrow margins for manoeuvre regarding the new scheme, plus the people's anger, plus only three months… The cabinet had this idea: "we are going to organise a *concertation* that will allow us to see what people really want and to see how we can adjust our system accordingly." (Interview 15, DGEC)[liv]

2.2. A specific assembly for a specific assemblage

Chaired by two high officials in close interaction with ministers and their staff, the *concertation* consisted in six thematic plenary meetings and numerous bilateral consultations. In parallel, the administration drafted proposals for a future arrangement of incentives that would fall within the perimeter allowed by existing legislation and take into account the outcomes of the *concertation* (Charpin et al., 2011, p. 6).

This *concertation* can be read as an attempt to channel the development of photovoltaic electricity generation through the conventional practices of French politics; some indeed refer to it as a typical *à la française* exercise masking technocratic decision-marking (Interview 18, representative of the photovoltaic sector). However, in spite of being yet another ministerial consultation, it turned out to be a rather unusual event, that one participant described as

> "extremely conflictual. A climate of discussion we rarely see in the consultation venues organised by public authorities" (Interview 17, utility).[lv]

Instead of closing down the political space created by feed-in tariffs for PV-generated electricity, it provided a stage for the enactment of a chaotic and controversial situation.

By gathering a large, diverse and passionate assembly, the *concertation* made visible the unintended consequences of feed-in tariffs for PV-generated electricity and the diversity of those affected by them, magnifying the political effects of feed-in tariffs. It thus provoked the emergence of a public. But the material and temporal frame it provided also constituted a space for negotiating how to attend to these consequences.

2.2.1. Mass and mess

The *concertation* enacted photovoltaics as a gathering in all its diversity. Seventy-four people or organisations were invited to plenary meetings, which took place in one large meeting room in the Ministry of Finance, and fifty-five bilateral meetings were held (Charpin et al., 2011, p. 5). A list of participants is provided in Annex 6.Then, as one of the organisers recalls,

> "there were all those that were not invited… […] there were insults, death threats, people trying to commit suicide…" (Interview 15, DGEC)[lvi]

Not only the number, but also the diversity of those willing to be heeded were striking. Both were a manifestation of the impact of feed-in tariffs for PV-generated electricity. These had radically transformed the photovoltaic sector, and their generosity allowed a great variety of business models and activities related to photovoltaics to thrive. The diversity of stakeholders reflected the great heterogeneity of the photovoltaic sector.

Because the photovoltaic value chain is very segmented, the sector included firms operating in very different realms: panels manufacture, system components manufacture, projects development, construction… Photovoltaic electricity producers were equally diverse, since photovoltaic installations can take many forms, and the tariff did not exclude any. Photovoltaic producers included promoters and manufacturers, but also comprised local governments, large utilities, social-housing promoters, individual households, artisans and agricultural cooperatives. Environmental NGOs and large utilities, farmers and bankers, local governments and members of Parliament, manufacturers and project developers, grid operators and representative of the building industry all sat around the same table.[136]

> This "made a difficult decision even harder to swallow, and the *concertation* extremely complicated, because in the same room you had *Touche pas à mon panneau solaire!* [a radical environmental association defending photovoltaics] and Pâris Moratoglu, the CEO of EDF-EN… […] You cannot lead a serene *concertation* in such a context." (Interview 16, representative of the photovoltaic sector)[lvii]

As feed-in tariffs for PV-generated electricity left room for virtually everybody on the market, they had allowed these stakeholders to cohabit in all their diversity without really needing to organise as a constituency. But, apart from their dependence on photovoltaic policies, these actors had little in common. They were not used to working together, and had very different, sometimes irreconcilable interests and objectives. The organisers of the *concertation* selected the participants in plenary meetings, but, as the sector was not structured, could not rely on a constituted pool of identified representatives. *Ad hoc* organisations as well as individual firms were thus invited, in addition to the more traditional participants to such events (industry representatives, representatives of local public authorities, grid operators…). As a result, those invited to the *concertation* were heterogeneous in what they represented: some attended on behalf of their company, representing private interests, while others were members of syndicates, unions or associations and represented collective interests. As one interviewee remarked, such a mix between private actors and spokespersons was confusing:

> "They had invited both professional bodies, associations, NGOs and private businesses, like Photowatt, Saint Gobain…, which attended *as such*, and not as representative bodies. And we said, this is a misdeal: you cannot have people representing a profession and others representing private interests. Of course we are not on the same wavelength. By definition." (Interview 36, enterprise).[lviii]

As a consequence of this gathering of unusual stakeholders, some of those invited were not accustomed to this type of negotiations and, as the future of their enterprises was often under threat, could take rather radical stances. In addition, any one who requested it could be audited individually, which added to the diversity of those heard. The atmosphere was thus somewhat odd, as one of the organiser recalls:

> "The atmosphere was very curious. When we meet people bilaterally, talk with people fro the SER, or from Hespul, we are if I may say "among well-educated people", their life is not at stake […]. They are reasonably virulent. They defend their point of view, but there are no insults, no standing up in the middle and slamming the door, it remains very smooth. And often, it is the same things with heads of Small and Medium Businesses, well, of businesses of a certain size: they'll win in negotiations sometimes, and sometimes they'll lose, they know they have to stay in good terms with the administration. But

[136] A list of participants is available as an annex to Charpin et al. 2011.

> during the *concertation*, there were people who were not used to this kind of exercises, of relations with the administration, or who had put so much money in it that for them it had become a matter of survival of their business, or of their own wealth, and who where much more virulent. […] There were small actors who had a business with 10 workers and who had managed to get invited at the *concertation*, and for them it was a matter of life and death, so they were a little bit more aggressive". (Interview 15, DGEC)[lix]

This unanticipated myriad of actors came in dispersed order as "a community of strange things", that is as "a relation, or rather a tangle of relations, among entities that do not belong to the same social world but are connected through an affair that affect them jointly" (Marres, 2005, p. 58). The dense agenda of meetings constituted one of these "occasion[s] in which a specific irreconcilability between modes of living comes to be articulated, as opposed to the many divergences among them that are often easy to observe, but rarely translate into *focused disagreement"* (Marres, 2005, p. 58, emphasis added). The *concertation* did not go smoothly, and is often described as a messy, cacophonic undertaking that occurred in a climate too tense to lead to productive discussions. Plenary meetings gathered between 50 and 100 people in a single room, intervening in turns to react on proposals and questions that the administration put forward:

> "All the associations that represented anything, however small, attended, and it was a choir of mourners in front of people taking notes*"* (Interview 17, utility).[lx]

2.2.2. Established institutions overwhelmed

Though the *concertation* constituted an attempt to channel the problems posed by the development of photovoltaic through the established practices of politics, it soon appeared clear that existing institutions and actors were not equipped to do so. The first effect of the *concertation* was to provide an arena for the display and discussions of the overflows triggered by FITs. It was thus a *political* moment, insofar as the devices, procedures and agents to address the deployment of photovoltaics as a novel issues had to be articulated along the issue itself.

Defiance and tension were exacerbated by the uncertainties about the exact status of photovoltaic markets that had made it difficult to adjust incentives (evolution of the prices of photovoltaic systems, segments of the photovoltaic value chain with the highest added value, number of "actual" as opposed to "speculative" projects, number of firms and jobs threatened by the moratorium…). The unanticipated pace and scale of the development of photovoltaics heightened these uncertainties for two main reasons: the quick and disorganised proliferation of projects and stakeholders, and the failure of established institutions, representatives and expertises to channel it. Market growth had gotten off tracks between 2008 and 2010, leading to a situation in which it was not sure who was in control – or whether anyone was. As an interviewee pointed out:

> "We were amateurs at every level. Because we had all been overwhelmed by the instrument." (Interview 35, utility)[lxi]

First, the rapid proliferation of actors dealing in photovoltaics had blurred the picture, especially when it came to analysing the actual status of photovoltaic projects in France. To assess the cost of support, one needed to know which share of the projects having requested FITs would actually be carried out. This uncertainty was illustrated by the reference often made to "speculative projects", supposedly encompassing a large share of projects, but whose origin was undefined. This uncertainty over who had "speculated" and was responsible for the bubble sparked suspicion and accusations. Besides, the diversity and disorganisation of participants made it hard to distinguish between legitimate and illegitimate **representatives of the sector** and to identify reliable messages from mere lobbying.

> "Some really have a well-structure stance and things to say, but many are out-and-out and one-dimensional lobbyists who won't let go of their position when it is not solid at all." (Interview 12, DGT)[lxii]
> "There's a myriad of actors […] who were given a platform during the *concertation*, but who according to us did not necessarily represent the sector, who sometimes represented very specific interests, the interests of actors who, through the creation of an association, were actually defending their own interests. So all of this was rather negative." (Interview 16, representative of the photovoltaic sector)[lxiii]
> "At the time, we were dealing with a photovoltaic sector that was not organised in terms of its representation. Virtually nothing existed. There was Hespul, but Hespul had a very bad reputation at the time, because they were perceived as eco-freaks…" (Interview 35, utility)[lxiv]

This was reinforced by the fact that established institutions had trouble keeping up with the fast development of the photovoltaic sector. State officials, electricity retailers and grid operators, and the traditional representatives of the renewable energy sector had not had time to readjust their expertise, tools and discourses yet.

The **EDF** group, comprising *Electricité de France* (EDF), *EDF-Energies Nouvelles* (EDF-EN), *EDF Obligation d'Achat* (EDF-AOA), *Réseau et Transport d'Electricité* (RTE) and ERDF,[137] was in a difficult and somewhat ambiguous position, because it included several entities with different and potentially conflicting interests. RTE and ERDF were managing two distinct project waiting lists, while EDF-EN was developing large-scale projects that represented an important share of these waiting lists. ERDF and EDF-AOA were respectively in charge of grid connection and purchase agreements, duties that they struggled to comply with, given the massive flow of projects. As an energy retailer and partly State-owned firm, EDF was also compelled by law to buy photovoltaic power at the price set by FITs, and was reimbursed by the CSPE. Because of its historical ties with government and administrative officials, some suspected EDF of collusion with the State.

> "A lot of things have been said, spread on no grounds, with no evidence, about the collusion of interests of some members of the SER, for instance with public authorities. Well, EDF, not to name them." (Interview 16, representative of the photovoltaic sector)[lxv]
> "EDF's stance was very badly received by the photovoltaic profession. For a reason that may be understandable, which is that we were not interested in the segment in which there were many SMB, so in the end we did not really stand by them. You could not expect the heads of EDF-EN to defend investments on roofs that earned their owners

[137] EDF, a former State monopoly, is now an independent utility which shares are still owned in majority by the French State. EDF-EN is a branch of EDF dedicated to renewable energy. EDF-AOA is the branch of EDF in charge of the management of purchase obligations. RTE is a public firm in charge of grid-operation, while ERDF, a public firm as well, is in charge of electricity dispatch. EDF, ERDF and RTE were separated as a consequence of the deregulation of the electricity sector, but retain historically strong ties as well as a close relationship with public authorities.

25%, and that overall threatened all renewable sectors when it came to public image. […] We perceived our stance as relatively balanced, but it is true that the fabric of photovoltaic SMBs felt like the big one was doing all right and left the small ones in dire straits. So we lived in a misunderstanding that was a bit burdensome for a while." (Interview 17, utility)[lxvi]

The **State**, on its part, had not anticipated the impact of FITs and lacked human resources and competencies to tackle it. An interviewee colourfully described it as "a cripple driving a Ferrari" (Interview 37, NGO). The government was blamed for its erratic management of incentives over the previous years. The stop & go that had prevailed since 2009 gave many actors the impression that it either did not really know what to do and was operating in a relatively careless manner, or simply wanted to sabotage the deployment of photovoltaics. The moratorium definitely undermined trust in its ability and/or will to steer the photovoltaic sector towards prosperity.

"Only five people are working on it [within the administration]: there is a problem of internal competencies and of lack of staff to steer [photovoltaics] carefully". (Interview 6, representative of the photovoltaic sector)[lxvii]

"Why have mistakes – because you have to call them mistakes – been done in the past and encouraged the speculative bubble? That also has to do with the lack of means available to professionals to write texts. We can denounce [sic] our interlocutors on this topic on the fingers of one hand. Including the central administration, so that is not a lot of people. To write the administrative order, there was one person. To steer this thing, to steer renewable sectors, and in general, for sectors with such dynamic costs evolutions, you need a reactive administration. And without means, you cannot have a reactive administration." (Interview 16, representative of the photovoltaic sector)[lxviii]

"Bad regulation, an autistic State that did not put enough resources in it. You have to realise that there was only one person working on the solar market, and not only that, at the DGEC. [...] And political decisions were belated, so when you say that the political decision is belated, it's, 'who benefits from the crime?' " (Interview 18, representative of the photovoltaic sector)[lxix]

"We have trouble knowing whether, in this matter, steering is really effective." "We can only take notice of an absolutely erratic management." (Claude Brottes, Member of Parliament, in Assemblée Nationale, 2010c)[lxx]

"This business, that costs 5 billions euros today, it concerns very persons, and nobody cares, actually. The Energy-Climate office at the DGEC that made the decision, back in 2009, that was three persons […] and they made decisions that involved several dozens billions euros in collective costs […]." (Interview 35, utility)[lxxi]

As to the **main representatives of renewable energy sector**, especially the *Syndicat des Energies Renouvelables* (SER), they were challenged in their representation and mediation roles. The recent evolutions of the photovoltaic sector had transformed the SER's membership, now dominated by project developers and promoters whose best interest was that tariffs remain high. This undermined the trust that the government and the administration had in the SER, who appeared to them as protecting the interests of those who had reaped most benefits from the misalignment of FITs.

"I think that is something I would blame [the SER for: they have lost the credibility we expected from them. At any rate, after a while, I thought, 'if I keep listening to them, we're heading for trouble'. And that is not their role. To be sure, they have a lobbying role, but I found them particularly unreasonable, and after a while they are no longer credible so we no longer listen to them." […] "[…] during this phase of relative turmoil, it

> felt like [the SER] represented only the interests of developers […]. And essentially the claim of developers is to do as many projects as possible so as to earn as much money as possible, and that is not at all the same as the claim of industrial developers who want less projects, but projects that use their own technologies. And to make people understand this, including in the hierarchy, in the cabinet, to say, 'beware, those you are meeting with are developers, so not businessmen, but close, and what matters is all the very small structures that we need to help one way or another', that is not an easy message." (Interview 15, DGEC) [lxxii]
>
> "It was an extremely difficult and complicated time, because internally, we were torn between extremely strong constraints; between a rock and a hard place, because we are pushed by members who, naturally, [do not want] a decrease, not to mention a moratorium on FITs, by public authorities who have an extremely strong pressure to control spending […]" (Interview 16, representative of the photovoltaic sector)[lxxiii]
>
> "The [SER] was a little outrun by its basis. […] Given the number of members they had, […] they had troubles taking very structured positions and having them validated by their members at the necessary speed." (Interview 17, utility)[lxxiv]
>
> "I think the photovoltaic sector did not do its job, they should have reacted right from the start and say: 'beware, they're setting up a trap!'. They cheerfully dived in, thinking, 'great! We have feed-in tariffs! Finally!... Except feed-in tariffs lasted for a couple of years…" (Interview 5, ADEME)[lxxv]

On the other hand, as a well-established syndicate, it had a large and diverse membership, including large energy firms, and a history of working closely with ministries. It was thus perceived as a moderate actor, and many of the new, more radical players felts it failed to represent their interests faithfully. The proliferation of new associations made the SER "a syndicate among others", further undermining its legitimacy as *the* representative of the photovoltaic sector (Interviews 6, 16, representative of the photovoltaic sector).

As a result, no competent authority stood out as a potential legitimate arbiter, since all were overwhelmed by the surge in photovoltaic activity. The debate was relatively levelled as boundaries between legitimate and illegitimate representatives were shifting. The need to re-establish trust and clarity was pressing, as noted Member of Parliament Geneviève Fioraso:

> "In the context of the advisory budgetary report on energy that I delivered, out of thirteen persons that I audited about photovoltaics, I got thirteen different opinions! This sector, more than ever, needs a pilot!" (Assemblée Nationale, 2010a, p. 16)[lxxvi]

2.2.3. Focusing disagreements over the issue of photovoltaics

When the *concertation* started, no clear analysis of the photovoltaic sector's recent developments was available, and the diversity and unruliness of participants challenged the legitimacy of traditional arbiters. There was agreement over the need to reform photovoltaic policies and markets, but how and what for was far from clear. The photovoltaic sector was not mapped out, and neither were the interests of participants. It was not clear who stood for what and who was legitimate. As virtually everything was contestable or contested, discussions were levelled to a surprising extent: the characteristics of photovoltaic modules, details of instrument design or price calculation techniques were just as important as the definition of overall objectives for photovoltaic development.

The *concertation* eventually allowed for the constitution of a form of common expertise. Over its course, those convoked to the meetings, who were initially concerned by photovoltaics only (or at least mainly) as market agents, developed a form of political agency on the matter. The organisation of the process itself contributed to this. By gathering actors concerned by photovoltaics in a single venue, it forced people into talking – something they had not needed to do before. However messy and disorganised, the *concertation* provided tools to foster collaboration: written contributions were circulated, email addresses were exchanged, positions where identified, participants organised into groups of shared interests...

> "At the first meeting of the *concertation* in December, we did not know who was around the table. There were lots of people, there were 60 persons; we knew some of them, but… I don't know how they gave invitations, but […] the first time I spoke, it was to ask that we have everybody's email. Because we had a paper with names, and that's it. No addresses, nothing. So I really insisted, and it allowed to discuss, to have exchanges between everyone." (Interview 3, NGO)[lxxvii]

This fostered dialogue and allowed all participants to get a clearer view of the sector. As a representative from the SER remarked, "the professionals we were did not have structured vision of the industry at the beginning of the *concertation*. Serious work has been carried out since then" (Poniatowski, 2011, p. 40).

The shock of the moratorium created a form of solidarity among participants (Interviews 2, 3, 37, NGOs), and the short timeframe and limited options incited the search for a common articulation of the issue. The agenda of meetings was defined along the way, in cooperation with the participants, which channelled discussions by identifying key issues. One meeting focused on the project waiting lists, two on specific categories of photovoltaic installations, two on the industry; the last was a discussion of the draft report (Charpin et al., 2011, p. 5). Six key issues and sources of uncertainties emerged: the project waiting lists, the structure of the industry, the overall targets and their breakdown among categories of photovoltaic systems, the relevance of BIPV, the design of incentives, and their mode of financing. Three questions seem to run through discussions: how much does it cost? Is it worth it? Along which procedures should it be done?

The report on the *concertation* gives a detailed account of these discussions, mapping out divergences and convergences (Charpin et al., 2011). The first meeting was meant to "exorcise the speculative bubble narrative" by disclosing information on the list of photovoltaic projects registered for FITs (Interview 15, DGEC). Not only did it spark a controversy on the legitimacy of some projects, it also highlighted the flaws of the waiting lists as indicators of the future cost of FITs. Indeed, the share of speculative projects versus projects that would be carried out could not be estimated with certainty.

Proposals to replace installed capacity targets with a cap on total costs followed. An NGO circulated a note that greatly influenced discussions (Hespul, 2010). It showed that this alternative metric could actually lead to more photovoltaic electricity generation at less cost, provided that the mode of calculating the CSPE was modified so as to best reflect the specificities and actual costs of photovoltaics. According to Hespul, this proposition "caused a sensation within the microcosm of the participants in the *concertation*. […] At least, there was full consensus on the method, the way to address the topic, the way to think about it" (Interview 3, NGO). It is indeed mentioned in several written contributions to the *concertation* (APESI, 2010; Touche pas à mon panneau solaire, 2011), one of which states that "the great majority of participants has said to be in favour of the use of Hespul's contribution to investigate [the CSPE calculation]" (Enerplan, 2011).

By gathering representatives from different segments of the photovoltaic sector, the *concertation* also drew a clearer picture of the industry and of the specificities of the different types of photovoltaic installations, making it possible to refine existing incentives categories. For instance, though BIPV remained hotly debated, there was an overall agreement on the need to distinguish between individual households, large roofs and ground-mounted photovoltaics.

The *concertation* also led some of its participants to constitute themselves as political actors on the topic of photovoltaic development. First, it allowed participants to identify the other stakeholders involved and map their positions and interests. And, subsequently, some attempted to build up actual political agencies, that is to say to consolidate their legitimacy and positions as representatives of the photovoltaic sector. The SER structured its approach to photovoltaics so as to reinforce its voice. Several organisms concerned by photovoltaics created the "*Etats généraux du solaire photovoltaïque*", an arena for them to discuss the prospects of French photovoltaics, negotiate a common position on some key issues, and map the topics on which they agreed to disagree.

> "In March 2011, quite a few of us thought that, in the end, we had been the victims of our own division. Almost consenting victims, organised by the French administration […] who had organised meetings of sectors taking care to invite as many people as possible, with an extremely large diversity of profiles, and people that were not prepared for that kind of meetings, in a total cacophony. All this allowed the Charpin team to say: you see, you do not agree among yourselves […] and the way to go is *this* way. And nobody was able to react. That was well organised. O, a few of us said: that must not happen again. We will have new steps, new debates to go through, and we need to be much better organised, and at any rate prepared, even if we know that in this sector as in many others, we cannot all agree. At least, we need to identify our differences, identify our agreements, put forward the agreements rather than the differences, and increase their number by more communication, more exchanges, etc. So that is what we did with the *Etats généraux du solaire*, by gathering over twenty organisms." (Interview 36, enterprise)[lxxviii]

Though large divergences persisted, participants thus started to develop a common approach to photovoltaics. Taking into account the uncertainties on future social costs and the need to contain these costs, the need for a market that could sustain the emerging industry, and the distinct dynamics of segments of installation, most agreed that a target between 700 and 1000 MW a year, split between categories of installations was an acceptable compromise (Charpin et al., 2011, p. 23). The suggested outcome leaned towards a mix of instruments able to keep the photovoltaic market on this track.

2.3. A paradoxical outcome: the politics of depoliticising feed-in tariffs

Still, despite its account of the diversity of positions, the final reports notes that "it is up to the government to decide whether the benefits of the photovoltaic sector […] justify the costs entailed by such development targets", leaving the fate of the photovoltaic sector in the hands of the government (Charpin et al., p. 23). Most participants agree in their analysis of the *concertation* and of its final outcome as a disappointment, or even a deception: no one was listened to and everything had been decided ahead, they say.

> "We have been fooled." (Interview 2, NGO)[lxxix]
>
> "What everyone observed was that [the *concertation*] was very disappointing, since all the decisions had in fact already been made beforehand." (Interview 17, utility)[lxxx]
>
> "The result is that in the end, it feels like the cards were dealt from the start." (Interview 16, representative of the photovoltaic sector)[lxxxi]
>
> "The so-called *concertation* was a schizophrenic thing. They did not listen to anything." (Interview 3, NGO)[lxxxii]
>
> "The State having failed in maintaining a regulation, we accepted the moratorium, but we have not been listened to any more than local governments, NGO or members of parliaments have been." (Richard Loyen, Manager of Enerplan, in Poniatowski, 2011)[lxxxiii]
>
> "[It was] an exercise which conclusion was written in advance, but in which we had to take part – unless we had all decided not to come, but we all hoped that it would not be pre-written." "When we started the first meeting of the *concertation*, all in all, the two-thirds or the three-quarters of what was concluded in the end were already concluded." (Interview 18, representative of the photovoltaic sector)[lxxxiv]
>
> "Exposing our viewpoint in such a short timeframe, when we feel like we have not been heard over the last three months, is a real challenge." (Arnaud Mine, President of SER-SOLER, in Poniatowski, 2011)[lxxxv]

2.3.1. Complicated assembly vs. complicated formulas

The moratorium ended on the 4 March 2011 with the publication of the *arrêté* setting a new articulation of incentives for grid-connected photovoltaics in France (MEDDTL, 2011).This *arrêté* was drafted by the administrative officers in charge of the *concertation*, but its design was a distinct process; it took into account what had been discussed, but only indirectly.

As detailed above (cf. 1.4.1. above) the new scheme – which was to be completed by calls for tenders to come later in the year – was explicitly designed to ensure that the target of 5400 MW of installed photovoltaic capacity in 2020 would *not* be overreached. It allows photovoltaic electricity generation to develop, but only within the restricted space that was intended for it. In that operation, the government overturned the meaning of the 2020 target. Initially intended as a signal to spark photovoltaic activity, hence to trigger actions the outcomes of which could not be predicted, it was turned into a limit that could pacify photovoltaic activity and keep it under control. As the head of the Climate-Energy office in the DGEC stated in front of the Senate in 2011:

> "To put it clearly, the Prime Minister agrees to pay for as much as 500 MW to see what it results in, but no more" (Poniatowski, 2011)[lxxxvi]

Because of its complexity and mathematical sophistication, this new regime was analysed not only as a serious restriction on the development of photovoltaic electricity generation, but also as an achievement in technocratic, engineer-led policy-making. Designed by the government and its administration, the outcome left members of parliament, industry representatives, local governments and associations equally perplexed.

> "Luckily, my administrator is a trained engineer and was able to provide a few explanations, but I admit that this document is slightly… complex." (Senat 2011, p. 53)[lxxxvii]
>
> "First, you can't understand [the *Arrêté du 4 mars 2011*] unless you are a Polytechnique graduate! At the time, we had a Polytechnique graduate […], luckily, and he understood it." (Interview 16, representative of the photovoltaic sector)[lxxxviii]
>
> "[To understand the *arrêté*] as it is written, you need to have an engineering school level in mathematics. Otherwise, you can't implement it. You can't understand it. This is anti-democratic. […] When you ask people at the DGEC about it, they say: 'oh well but this is the only way we know, the only thing we know how to do is equations'. That's very telling about their state of mind. Local installers cannot understand that thing! It's impossible, I mean, culturally! There is no FIT grid, only a set of esoteric symbols." (Interview 3, NGO)[lxxxix]

The new support scheme reflected the government's will to master full control of the development and cost of French photovoltaics. The *concertation* had changed nothing to the government's fear of seeing photovoltaics go off track again: they wanted to take as little risk as possible.

The collective gathered during the *concertation* managed to focus disagreement and reach a common ground to some extent, but its articulation of the issue did not survive outside of the microcosm of the *concertation*. It failed to convince government officials, who did not recognise it as reliable. Either the *concertation* mission did not explain the logic and observations that supported its proposals, or the government could not accept the articulation of photovoltaic development it offered, but the Prime Minister's staff eventually decided not to trust this collective, discarding the few compromises it had reached:

> "We proposed [800 MW a year] to the cabinet, and then there was a meeting at the Prime Minister's level, where there were people from [the Ministry of Economy], people from [The Minister of the Environment]'s staff […] and it went wrong, it's 500. At some point, the Prime Minister's adviser lost her nerves, she said: 'but no, you're not able to tell me how much it costs!' – because she looked back at the past, asking how much would be carried out. It was at the time when we knew that there were 4000 MW in the pipelines, that we had done 1000 or 1500 MW, but we did not know roughly how many were left and how many would really be carried out. Maybe we communicated badly on uncertainties during this meeting. In the end, her logic was: 'you are not able to tell me how much this costs, and you want to do more than the 500 MW a year that were initially planned? You must be kidding me, this is going to blow up on our faces!' So we staid at 500.'" (Interview 15, DGEC)[xc]

The choice to incorporate adjustment mechanisms within the design of incentives reflected the will to take responsibility for dealing with the uncertainties on the evolution of the photovoltaic market away from a concerned collective that seemed too diverse and untamed to be relied upon. The failure of the profession to give signals of the misalignment of FITs and costs had triggered suspicion that industry representatives were primarily defending private interests, so the government decided not to trust the emerging public; but neither did it want to take the responsibility of adjusting FITs upon itself. It thus delegated it to a set of mathematical and legal devices that it considered as the fittest way to keep track of the dynamic of the photovoltaic market (Interview 12, DGT). Provided that they were well calibrated from the start, these stand-alone mechanisms were not supposed to require any further intervention from neither insufficiently reliable forecasts nor unruly stakeholders. Crucially, they were also supposed to prevent the unruly proliferation of grid-connected photovoltaic installations.

Yet, the calibration requires a form of negotiation and expertise, if only to distinguish between the specificities of different categories of photovoltaic projects. The sophistication and refinement of the scheme may not have been possible without the *concertation*. Besides, the success of the calibration can only be assessed through experience, and, in that, the emergence of a structuring, potentially contesting public during the *concertation* may play an important role.

2.3.2. Balancing uncertainty

The anti-political character of the new support frame is not a problem *per se*. As Barry noted, the collective needs to reach common views and disagreement sometimes has to be contained; what matters is that anti-political action recognizes the existence and value of a diversity of views (Barry, 2002, p. 271). Stabilising the photovoltaic market required the institution of rules and codifications able to maintain market framings in an unstable and uncertain context. The choice to circumvent the proliferation of photovoltaics with sophisticated, self-sufficient mechanisms was a way to contain, channel and control both an unpredictable market and an undisciplined collective. Other means of fulfilling that role could have been devised, but the government's choice should be assessed primarily in the light of its ability to do it.

The re-designed instruments have been criticised, not so much in their principle, but mostly regarding their ability to sustain the French photovoltaic sector and to adjust to the evolution of the market. Simplified calls for tenders have been said to encourage the purchase of cheap – and for the most part Chinese – photovoltaic modules. As to FITs, doubts have been expressed about the reliability of decrease indicators, and the decease rate is widely considered too high, reversing the pre-moratorium situation – tariffs now decrease to fast for investors to follow.

At any rate, they do not provide enough space to sustain the emerging sector and to compensate for the destructive impact of the moratorium. To an extent, it is a way to "cleanse" the landscape and to keep actors from overflowing. Still, the market has collapsed and is now wavering. In the first trimester of 2013, grid connections have fallen to their lowest level in several years (Les Echos, 2013), and most industrial actors have drastically reduced their activity, waiting for better days to come.

The market slowdown cannot be solely attributed to the management of incentives; the global dynamics of photovoltaic markets have grown increasingly unpredictable, and a lot remains out of the scope of domestic regulation. However, the outcome of the moratorium did nothing to protect the sector. What is at stake in the regulation of the photovoltaic market is not the reduction of uncertainty, but the allocation of its burden.

The March 2011 *arrêté* marked a shift from a situation in which all the impacts of market uncertainties fell on the consumers' and the government's side to one in which the State has perfect control over how incentives will affect it, while the photovoltaic sector has none (it is not even possible to know the level of FIT from which a project will benefit in advance). This made manifest a power asymmetry as the State asserted the dependence of the photovoltaic market upon it. The sophistication of regulations written in a mathematical language only engineers can read fluently, the inflexibility of ministers, and the depublicising character of a frame explicitly designed to avoid any further political intervention reinforced this asymmetry, leaving a large part of the photovoltaic sector virtually powerless and fuelling disappointment.

Aside from containing the cost of supporting photovoltaic electricity generation, the outcome of the moratorium did not provide a very effective or sustainable way of managing the uncertainties of an emerging market. The new government announced a punctual increase in FITs in January 2013, and the fate of the sector currently hangs on the undergoing debate on the energy transition, which reopened political discussions. Because photovoltaic markets have not been pacified yet, they still call for political management. However, as the study of *concertation* suggests, this political management treads on a fine rope: the need to stabilise markets makes it difficult to leave spaces of dissensus open too long, because the concerned collective tends to overflow too much, and because this heightens uncertainty to a degree that threatens market activity.

Conclusion

In this chapter, I have detailed the evolution of French photovoltaic policy and its effect, with a focus on the years 2008 to 2011. Photovoltaic support in France is mainly articulated around feed-in tariffs, and I have paid attention to the design and material arrangements of feed-in schemes as well as to their actual effects. I have shown how FIT-supported photovoltaic markets were allowed to overflow to a surprising extent, and how this rapid and overwhelming growth led to a sudden political and market crisis when the government tried to take back control over the sector. The French case, I argue, is peculiar insofar as it moved very rapidly from on extreme to another. Until 2010, photovoltaics were generously supported as a market but barely acknowledged as a political issue; by late 2010, they had become a dramatic political problem which was addressed by strictly bridling market deployment.

Interestingly enough, the first feed-in tariffs for PV-generated electricity established in 2002 and largely inspired from the German model could have worked as a political market *agencement*. It was design so as to adjust to the evolution it triggered, and could therefore have triggered a process of channelled actualisation. However, it was calibrated at such a low level that it could not trigger any change, except in overseas territories: it reflected a political compromise that did not allow for the mass development of photovoltaic electricity on the grid.

In 2006, the reformed FIT scheme was explicitly targeted at a niche market; as a political *agencement,* it articulated the deployment of photovoltaics as a marginal issue posing virtually no threat to the *status quo*. In other words, as the scheme was not considered to have much potential for actualisation, no mechanism for channelling its effects were designed. Yet, the extremely secure and interesting transactions that it framed triggered an unchannelled and hardly documented expansion of photovoltaic markets which was eventually turned into a political concern. In the absence of institutional equipment to manage the rapid emergence of photovoltaics, this resulted in concerns about the social and political cost of feed-in tariffs for PV-generated electricity and, eventually, in a political shock (the 2010 moratorium) and in the creation of an *ad hoc* political arena to address the problem (the *concertation* organised by Charpin and Trink).

The moratorium and the *concertation* can be read as attempts to stabilise the issue of photovoltaics and to channel it through existing institutions; but these attempts in fact overflowed. An effect of the moratorium was to create additional uncertainties and mistrust and to turn not only the development of photovoltaics, but support to photovoltaic electricity itself, into a political problem by generating the emergence of a public of actors affected by the matter. It turned those that FITs had constituted into economic agencies into political actors, though their political capacity remained limited. Indeed, the outcome of this phase, as expressed in the *Arrêté du 4 mars 2011,* was a support scheme that stressed the means to channel and control its effects but, as a result, provided very little space for innovation, change and actualisation. The difficulty to re-calibrate feed-in tariffs for PV-generated electricity, and the failure of the emerging public to articulate the issue in a way that would have allowed the government to adjust feed-in tariffs accordingly also stress that "right price" of feed-in tariffs is not a pre-existing entity that only needs to be discovered. It is negotiated and articulated along with the collective of those interested by photovoltaics (including photovoltaic project developers, industries, public authorities, electricity users, etc.) and needs to be adjusted not just to the evolutions of photovoltaic costs but to the reconfiguration of this collective. This highlights the interweaving of the market and political dimensions at play in feed-in tariffs for PV-generated electricity as *agencements.*

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[i] "L'un des experts de l'ADEME réalise des études comparatives à partir des cas danois, allemand et californien. Il constate que le point commun entre ces différents exemples de succès pour les renouvelables, et notamment l'éolien réside dans leur système de tarification incitative. A l'occasion d'un colloque organisé en 1991, il se fait l'avocat d'un système de 'tarifs d'achat' qui ont, selon lui, permis le décollage de filières renouvelables émergentes."

[ii] "Si tous les acteurs semblent reconnaître la plus grande efficacité [du système de tarifs d'achat] en termes de capacité éolienne installée, EDF insiste sur les aspects économiques, notamment la baisse des prix que devrait occasionner le mécanisme d'appel d'offres."

[iii] "Après, il faut revenir aux fondamentaux de l'obligation d'achat, qui est qu'on a une politique énergétique décidée par les pouvoirs publics, prise en charge par une entreprise privée, et non financée par l'impôt, parce que c'est une taxe. Donc on a un outil, là, qui est quand même assez original, quand même ! c'est un truc assez... enfin vous me direz si vous avez vu, mais moi je crois pas que ça existe autre – enfin sous cette forme là dans d'autres secteurs en France. C'est un truc assez hallucinant."

[iv] "C'est une véritable industrie des énergies renouvelables qu'il nous faut développer. [...] Il ne s'agit plus seulement de subventionner votre secteur pour le maintenir dans une logique d'appoint, mais de vous aider à conquérir des marchés dont l'importance a été trop longtemps sous-estimée."

[v] "Les systèmes de prix garanties sont les seuls à même d'accélérer le développement des filières renouvelables et de leur permettre d'atteindre la maturité industrielle."

[vi] “Ces tarifs doivent être simple, clairs et accessibles. Leur niveau doit être déterminé en fonction des effets réels et attendus sur les filières, et non par des éléments externes, liés à la structure actuelle du système électrique, tels que les ‘coûts évités de long terme’ selon les calculs habituels. Ils doivent être assortis de mécanismes d’indexation et de révision transparents, annoncés à l’avance et stables pour sur [sic] une durée suffisante pour avoir le recul nécessaire à une évaluation fine de leur impact.”

[vii] “S’il s’agit d’éviter un dérapage quantitatif dont on craint qu’il soit difficile à contrôler dans le cadre d’une obligation d’achat, la fixation de volumes globaux annuels éligibles, soit en termes de puissance installées (en MW), soit en termes d’énergie produite et achetée (en MWh) complétée éventuellement de quotas par opérateur (ou type d’opérateur) ou par filière, aurait pu répondre sans inconvénient à cette légitime préoccupation.”

[viii] “Ces programmes [de soutien au photovoltaïque raccordé au réseau] ne sont pas prioritairement motivés par des objectifs de contribution quantitativement significative à court terme du photovoltaïque à la consommation d’électricité […], mais par une volonté de soutenir les positions d’une industrie nationale dans la perspective d’une compétition ouverte dans un marché qui s’annonce extrêmement prometteur à horizon 2020-2030. Les résultats de ces programmes sont bien réels, puisque l’on constate que le photovoltaïque figure parmi les filières industrielles les plus dynamiques” (p. 118).

[ix] “Là aussi, pour la petite histoire, comment il a été décidé le tarif photovoltaïque à l’époque : c’est un arrêté de 2002, mai 2002 je crois. En fait EDF, qui était à l’époque encore public, vraiment a freiné des quatre fers. Nous on était dans toutes les discussions donc on a vraiment... et en fait, ben en voulait pas, de ce tarif d’achat photovoltaïque, c’était vraiment... ça leur arrachait le cœur, et ils avaient bloqué complètement sur un truc, c’était pas plus d’1F. Parce qu’à l’époque on était encore au franc, c’était en 2000. “N’y pensez pas, 1F c’est déjà énorme, on n’ira jamais au-delà d’1F”. Le résultat concret, c’est que le tarif d’achat en avril 2002 a été de 0,1525 d’euro - 15,25c€. Ce qui vaut 1F.”

[x] “Ca vient du fait que 30 centimes ça suffisait pas, à l’époque. Maintenant on pourrait presque s’en satisfaire, mais sur des systèmes simples avec des panneaux standards, il fallait monter au moins à 45-50, on aurait pas de problèmes de demander des subventions etc. Donc l’Ademe a poussé pour cette idée, et il y a eu des malins en face qui se sont dit, tiens, on va prendre ça, comme ça – moi c’est ce que j’avais écrit à l’époque – le photovoltaïque à la niche !”

[xi] “Cet arrêté tarifaire, il est pas cadré, en fait, parce qu’il vise pas forcément les particuliers, il vise pas les industriels... Il ne donne pas d’orientation de développement à la filière, en fait. Il est polyvalent. Il est très, très ouvert, polyvalent, et il ne donne pas d’orientation à la filière. Du coup, tout le monde va y aller, avec des taux de retour sur investissement qui sont hallucinants – parce qu’à l’époque, ça se double des aides de l’Ademe, enfin des agences régionales de l’énergie, du crédit d’impôt – y a 50% de crédit d’impôt sur le matériel, quand même –, des aides régionales...”

[xii] “Après, on avait une puissance publique qui était complètement dépassée par ce succès, et qui plutôt que d’améliorer le *process* ou de le piloter, a supprimé tous les dispositifs de contrôle. Parce qu’ils ont supprimé l’autorisation d’exploiter, qui devait être faite sur le site Ampère à l’époque ; comme ils avaient pas les 30 000 euros qui allaient bien pour le mettre à jour et faire en sorte qu’il supporte la charge, ils ont dit : on supprime l’autorisation d’exploiter. Mais ils arrivaient plus à faire les CODOA dans les DREAL, ils ont dit : ben on supprime les CODOA. Eh ben oui, c’est tellement plus simple comme ça ! euh... et donc, on a une puissance publique à qui le dispositif a complètement échappé, finalement.”

[xiii] “Après il y a eu des ajustements, parce qu’on s’est rendu compte qu’il y avait des choses qui n’allaient pas. Non, au niveau technique je crois qu’il n’y a pas eu trop de modifications sur le fond, par contre sur les usages, les critères périphériques du bâtiment, la grille a beaucoup changé à chaque fois, parce qu’il y a eu des volontés de dire : ‘il faut faire sortir les agriculteurs, il faut que le bâtiment soit fermé, pas ouvert…’ – ça c’était pour le hangar ouvert aux quatre vents, finalement on tombe sur ça… ça a été un peu chaotique comme gestion. […] Il y avait des petits

arbitrages comme ça où on sentait que les critères étaient pas optimum, mais grosso modo ça marche quand même."

[xiv] "[...] chaque trimestre, on ouvre une période où les gens candidatent, et on ne sélectionne que sur le prix, qui est finalement la seule chose un peu objective sur laquelle on peut sélectionner, et que le meilleur gagne. Et si vous êtes pas pris, le trimestre d'après, vous pouvez recandidater, revoir votre projet, y a pas de soucis. On est à la limite de ce qui est juridiquement faisable, parce que c'est un appel d'offre unique, mais coupé en tranches, c'est assez curieux ; mais on l'a tenté, et ça se passe bien. [...] Ca a un défaut, c'est que ça favorise le panneau le moins cher, donc plutôt du chinois. Mais de toute façon, sur ce segment là, comme c'est des petits acteurs sur lesquels on n'a aucune prise politique, on n'avait aucun moyen de les inciter à choisir des panneaux français ou des technologies françaises."

[xv] "C'est vrai que pour une fois, et ça c'est l'avantage de l'appel d'offres, […] c'est transparent. Ca a la vertu de mettre tout à plat, et l'administration choisit en connaissance de cause les tarifs, et on a accès à un tarif marché à un instant t. Ca c'est très important, parce que même pour nous au SER, c'est compliqué d'estimer, de faire confiance à nos adhérents pour l'estimation du tarif, d'un tarif juste."

[xvi] "[...] je pense que c'est une des victoires de la DGEC [...], c'est qu'on a réussi à segmenter l'appel d'offres en des tas de lots bizarres – enfin, qui paraissaient aux gens bizarres – mais qui permettent de cibler certaines technologies qui nous semblent prometteuses, pour lesquelles il y a des acteurs français. Mais ça a été de haute lutte [...]. On a réussi à trouver une solution, je pense quelque chose qui tient la route, qui sera pas forcément très reproductible d'année en année, mais qui au moins a permis à ces entreprises d'avoir une première réalisation. Sinon ils ne l'auraient jamais eue. Et après, à eux de s'exporter. »

[xvii] "Sur le résidentiel, la demande de raccordement correspond peu ou prou à un projet qui va se faire effectivement – 95% dans le résidentiel, quand vous avez une demande de raccordement qui est posée, le projet se fait ; vous avez un très faible taux de chute, parce que c'est plus petit, les investissements sont moindres, c'est sécurisé... En revanche, pour les projets de plus grande ampleur, vous avez pas mal de questions qui se posent, en particulier la question du financement. [...] l'indicateur de décroissance n'est pas adapté. Ce qu'il aurait fallu prendre à l'époque, ça aurait été les PTF signées, acompte payé : quand vous signez votre PTF, que vous donnez l'acompte, là vous pouvez dire que votre projet est assez avancé pour être sérieux et mené à son terme."

[xviii] "Un secteur où vous avez une décroissance de 10% des coûts par trimestre, j'en connais pas ! ça n'existe pas."

[xix] "C'est-à-dire que, finalement, le débat sur la transition énergétique prolonge cette période d'incertitude, puisque, aujourd'hui – et c'est compréhensible, on peut l'accepter – le gouvernement ne peut pas prendre des mesures fortes, puisqu'il compte sur les résultats du débat pour mettre en place une loi de programmation […] pour fixer les axes de développement en termes d'investissements énergétiques pour la France pour les […] 15 ans qui viennent. Et donc, cette réflexion là a un effet sclérosant sur la situation actuelle. Donc, tant qu'on ne sera pas sortis de ce débat, qu'on ne sera pas arrivés à une conclusion et à un gouvernement qui exprimera réellement ce qu'il veut faire sur la base des conclusions de ce débat, on est dans une phase d'attente, qui est terrible parce que la filière ne peut pas attendre. Ca a été exprimé, ça a été entendu, il ont pris quelques mesures, on va dire mesurettes, mais qui n'ont pas l'effet nécessaire – mais ça, on le savait. […] On est dans l'attente, et on est dans une attente qui est doublement terrible, à la fois par rapport au fait que le niveau d'activité est très faible, et donc ne permet pas, aujourd'hui, à beaucoup d'entreprises de durer encore longtemps. On est vraiment, pour beaucoup, en sursis. Et c'est terrible, parce qu'on ne sait pas sur quoi ça va déboucher. On a beau avoir un gouvernement et un président qui a annoncé des objectifs, on voit bien aujourd'hui que ces objectifs pourraient être reniés."

[xx] "On peut donc en conclure que la production solaire photovoltaïque ne participera pas significativement à l'équilibre offre/demande de la France continentale d'ici 2015." The sentence is in bold letters in the report.

[xxi] "En Corse, dans les départements d'outre-mer et à Mayotte, pour une entreprise, le tarif conduit, dans tous les cas de figures étudiés, à une rentabilité très élevée. A tarif égal avec la métropole continentale, l'augmentation du gisement suffirait, à elle seule, à couvrir une augmentation du coût des équipements de l'ordre de 20%. Il n'est donc pas nécessaire de majorer le tarif en comparaison de celui applicable en métropole continentale. D'ailleurs, le développement constaté de la filière dans ces zones, alors que le tarif en vigueur est approximativement égal au nouveau tarif proposé en métropole continentale, démontre le caractère inutile de la majoration proposée."

[xxii] "L'ambition de la France est de jouer un rôle de premier plan au niveau mondial dans la révolution technologique qui s'annonce. Pour cela, il est nécessaire de dynamiser très fortement le marché francais, d'accélèrer la recherche et de bâtir une véritable industrie solaire en France."

[xxiii] "Je pense qu'au début du tarif, c'était vraiment la vitrine, les gens savaient que c'était extrêmement cher le photovoltaïque, donc c'était plus un outil de promotion de l'ensemble des énergies renouvelables ; et plus le temps est passé, quand on a commencé à en installer massivement, c'était plus tenable de mettre autant d'argent sur quelque chose qui était juste un symbole."

[xxiv] "Et donc, c'est gens avaient l'habitude d'une manne qui allait augmentant, ils allaient voir des ménages à qui ils disaient : 'vous n'allez quand même pas mettre votre argent à la Caisse d'Epargne alors qu'en posant un panneau sur votre toit, vous avez presque exactement le même taux de risque qu'à la Caisse d'Epargne (il peut être cassé, et encore je vais vous donner une assurance), et au lieu de vous rapporter 4%, ça va vous en rapporter 15'. Et encore, quand je dis 15, il y avait des projets pour des ménages dans les régions ensoleillées à l'époque qui d'après le rapport Charpin allaient jusqu'à 25. Et donc les gens vivaient, ils étaient dopés à la subvention."

[xxv] "[se vanter d'avoir les tarifs d'achat les plus élevés du monde], c'était dire aux investisseurs : 'venez, vous allez gagner plein d'argent, vous allez avoir des TRI de 20-25%'. C'était la réalité ! Le tarif à 55 voir 60 centime d'euros plus les 50% de crédit d'impôt, nous on l'a toujours dénoncé. C'était de la folie. Plus la TVA à 5,5... et quand des particuliers se vantent d'avoir des temps de retour sur 5 ans, avec des contrats de 20 ans... c'était n'importe quoi."

[xxvi] "Quand vous avez des TRI qui sont supérieurs à 10%, et qui sont parfois à 20, 30% ou plus, les cascades défilent. Le pire que j'ai vu, c'était des véhicules financiers en ISF-TEPA qui montaient des cabinets de vente et d'installation, qui investissaient dans des sociétés de vente et d'installation pour les particuliers, qui eux-mêmes bénéficiaient du crédit d'impôt sur le système, plus un tarif d'achat qui était élevé. A un moment, on était le photovoltaïque le plus subventionné du monde. C'est pas vertueux pour les acteurs économiques, parce qu'ils ne font pas d'efforts. Ca ouvre à la porte à tous les margoulins qui disent : 'mon dieu, on transforme le photon en or ! Il faut que j'en profite, il faut que j'en croque !' "

[xxvii] "Je pense que sur le photovoltaïque on s'est dit que c'était un gadget, 'mettons un grand tarif, ça fera un affichage'. Sauf qu'au bout d'un moment... les six premiers mois il ne s'est rien passé, puis d'un seul coup il y a eu un em-bal-le-ment. Je crois qu'ils n'avaient pas réalisé qu'à un moment donné tous les installateurs allaient se mettre à faire du photovoltaïque, les gens allaient faire n'importe quoi, bien sûr on rajoute un tarif mirobolant, on met 50% de crédit d'impôt... donc les gens ont vendu plutôt du placement financier, il y avait très peu de motivation énergies renouvelables là-dedans. Les gens qui sont passés au photovoltaïque, 90% de leur motivation, c'est une motivation pécuniaire : 'je fais un placement financier intéressant, j'ai un tarif garanti sur 20 ans, mon soleil je le connais à peu près'. Là-dessus, vous rajoutez pour les particuliers des installateurs au mieux mal formés, au pire malhonnêtes, et vous avez une pétaudière. Mais je ne pense pas que les autorités étaient conscientes que ça allait rencontrer un si grand succès ; le tarif a dû être fait sur un coin de table."

[xxviii] "Ca a commencé vraiment à augmenter à partir de 2008-2009 en fait, parce qu'à ce moment-là, décroissance des coûts, les marchés s'ouvrent un peu partout dans le monde, et donc, la machine commence à tourner à plein régime, puis après en surrégime."

[xxix] "On a dit aux pouvoirs publics fin 2009 : 'nous, les flux mensuels qu'on voit arriver à ERDF, ils nous paraissent préoccupants. D'abord, on vous préviens, ERDF ne va pas arriver à respecter

les délais, parce qu'ils ne sont même pas capables de recruter des gens à la vitesse qu'il faudrait ; et d'autre part, vous ne le verrez pas dans la CSPE de cette année, mais vous le verrez dans la CSPE d'ici 2 ou 3 ans, et vous le verrez pour 20 ans."

[xxx] "Il y avait des caisses de courrier qui arrivaient par quinzaines... rendez-vous compte, on a reçu plus de 50 000 demandes de contrats en un mois. En décembre. C'était colossal. On travaillait le jour et la nuit à l'époque. C'était... c'était vraiment colossal."

[xxxi] "Pour vous donner quelques chiffres quand même, quand moi je suis arrivé en 2008, on faisait dans l'année 100 certificats [ouvrant droit à l'obligation d'achat]. Je suis arrivé le 1 er septembre 2008. En octobre-novembre 2008, on commençait à passer à 100 par mois au lieu de 100 par an ; et la dernière année où on en a fait, ça doit être en janvier 2010, on en faisait *1000* par mois. […] Quand je suis arrive, moi, c'est un peu le hasard, mais la machine commençait à être asphyxiée. C'est-à-dire que quand je suis arrivé – alors, normalement, on a deux mois pour traiter ces certificats. On était péniblement à deux mois, avec un effet extrêmement pervers : c'est-à-dire que les dossiers arrivaient, s'empilaient, il y avait deux personnes pour les traiter, et quand quelqu'un appelait pour savoir où en était son certificat, le temps de retrouver le certificat dans la pile, voyez, ben en fait on traitait pas de certificat..."

[xxxii] "J'ai eu des discussions informelles avec eux, ils sont venus à Lyon nous vor en décembre 2009. Il avait fallu les supplier d'abord pour qu'ils viennent. On leur dit : mais rendez-vous compte ! Il faut faire quelque chose, regardez ! Enfin, le but, c'était qu'ils voient qu'il y en avait partout et qu'on n'arrivait pas à faire face."

[xxxiii] "J'expliquerais, d'ailleurs, une grosse partie des difficultés du photovoltaïque par le fait que ça se soit développé à la marge des filières habituelles, et que les remontées d'information, et notamment les remontées d'informations en nombre d'installateurs, et toutes les données sectorielles, ne soient pas remontées au gouvernement et que le gouvernement n'ait pas vu l'inflation de ce secteur [...]. Cette montée en puissance là [du nombre d'installateurs] n'a pas été relevée par les instances habituelles du bâtiment. Et donc l'État n'a pas eu la remontée d'information. […] Le chiffre d'affaire s'est dilué complètement... c'était trop petit encore pour que le système bancaire s'organise et remonte de l'information sur les volumes de financement. Si vous voulez, cette flambée du photovoltaïque entre 2007 et 2010, elle s'est faite à la marge. Totalement à la marge. Et je pense que c'est très lié à la nature des installateurs, qui n'ont pas les profils habituels des gens du bâtiment. On avait un nombre de bac +5 sur les toitures impressionnant. Et ça, ces gens-là ne pensent pas syndicat, habituellement, ne pensent pas représentation. Ce sont des gens qui ne sont pas habitués à aller s'inscrire dans un syndicat professionnel."

[…] Le problème, c'est la durée de remontée d'information au ministère. Quand vous avez un secteur dans lequel vous avez des coûts de production qui se divisent par deux tous les trois ans... les ministères, eux, ils arrivent à s'équiper – moi je le vois en ce moment, dans le débat national, on travaille sur des données statistiques qui datent pour la plupart de 2011. Donc si vous voulez, le temps de latence était tel que... voilà, c'est comme si vous aviez un paralytique au volant d'une Ferrari."

[xxxiv] "Des premières informations en direction des cabinets ont été données en 2009, sur le fait qu'il commençait à y avoir trop de projets par rapport aux objectif, que tout ça coûtait fort cher et que ce n'était pas logique que les tarifs continuent de croître alors que les coûts de fabrication baissaient."

[xxxv] "Il y avait un groupe de travail qui devait se faire à l'automne, ça ne s'est pas fait pour beaucoup de raisons. On a pris un peu de retard, et en trois mois... !"

[xxxvi] "Toute cette phase un peu agitée, on va dire à partir de juillet, août, septembre, octobre, et puis le moratoire en décembre... [...] ce n'était pas la crise, mais enfin, ça se faisait dans une certaine urgence. Ne serait-ce que parce que chaque jour, on avait fait des calculs, c'était quelques millions d'euros de projets qui se faisaient et qui allaient impacter la facture d'électricité."

[xxxvii] "Les problèmes rencontrés sont à la marge. [...] Le développement de la filière photovoltaïque à 500% était la seule façon d'atteindre nos objectifs. Ce n'est pas parce qu'on baisse de 12% une partie des tarifs qu'on ne maîtrise pas la croissance."
[xxxviii] "... en janvier, je pense que les cabinets n'avaient pas pris la mesure de ce que ça représentait sur la facture, malgré toutes les notes qu'on pouvait leur envoyer. Borloo avait fait du photovoltaïque sa vitrine. [...] Ou s'il s'en est rendu compte, il s'est dit que l'avantage médiatique qu'il en retirait était suffisant pour continuer. En août, il a infléchi un petit peu mais ça restait quand même haut... Il a vraiment fallu attendre le changement de gouvernement et l'arrivée de NKM pour que les choses... enfin, tout d'un coup les gens sont devenus beaucoup lus sensibles à l'argument : 'mais mon dieu mais tout ça coûte des milliards et va augmenter les facture d'électricité, on arrive près des élections, ça va poser un problème.' "
[xxxix] "On a vu que nos arbitrages ne se faisaient plus au ministère de l'écologie mais à Bercy, après la crise [...], et puis ensuite au cabinet du Premier Ministre, mais en aucun cas au ministère de l'écologie. C'était : on change notre fusil d'épaule, combien ça coûte ?"
[xl] "Ils étaient vraiment extrêmement inquiets. [...] On n'était pas si loin que ça d'une période électorale, et l'État avait très peur, et l'État a été très raide."
[xli] "[Le moratoire] avait une solidité juridique meilleure, parce que c'était un décret, c'était prévu dans la loi qu'il était possible d'en faire. Ca laissait du temps après pour écouter les gens. Et ça nous laissait beaucoup plus de latitude sur les moyens de transition en fait, pour définir clairement ce qui subissait le moratoire et ce qui ne le subissait pas."
[xlii] "Parce que c'est violent, c'est-à-dire aujourd'hui c'est des entreprises avec des licenciements."
[xliii] "Avec une action comme ça, le problème, c'est que non seulement vous réduisez le volume de manière drastique, mais [...] ça fait énormément de dégâts, et vous touchez le cœur des acteurs, et pas uniquement les acteurs nouveaux qui peuvent... pas seulement les promoteurs en un mot, c'est ça."
[xliv] "... et le choc, le fait que pour ces toutes petites entreprises, c'était vraiment leur existence qui était en jeu. C'était indéniable, je veux dire, même nous, nous plaidons contre le stop & go. »
[xlv] "Tout stopper, c'est tout simplement signer la mort des petites entreprises qui ne peuvent pas perdre trois mois ! »
[xlvi] "Le moratoire va tuer les PME et les ETI !"
[xlvii] "Vous les tuez aujourd'hui et il ne restera plus sur le marché qu'EDF et l'ex-GDF –bref, une solution à la française..."
[xlviii] "On tue des professionnels."
[xlix] "L'annonce du moratoire pèse largement sur le carnet de commandes que nous avons constitué patiemment à la suite du retournement du marché, en 2008."
[l] "[...] le décret du 9 décembre anéantit deux ans de travail. [...] Il est inadmissible que des décisions prises dans l'urgence puissent saborder tant de travail !"
[li] "Ce sera la mort de notre industrie et de toutes les ambitions futures."
[lii] "Le moratoire français est sans doute la pire des solutions, la plus catastrophique en termes de visibilité – et les banques ne veulent d'ailleurs plus prêter."
[liii] "Nous ne voulons pas mourir », « La filière meurt et aucune PME ne subsistera."
[liv] "Trois mois, c'est relativement court dans l'administration, on n'a pas le temps de révolutionner le monde. En particulier, l'analyse qu'on a faite [...] c'est de dire : si on veut changer le système de tarif d'achat de façon lourde, on va être embêtés parce qu'il faudrait modifier la loi. [...] Si on voulait faire un truc intermédiaire, on n'avait juste pas le temps, parce qu'il fallait modifier la loi, des décrets en Conseil d'État, c'était l'horreur. Donc du coup, quand on a vu qu'on avait des marges de manœuvre relativement serrées, enfin, faibles, sur le nouveau dispositif, plus la grogne des gens, plus on a trois mois... donc c'est le cabinet qui a eu l'idée de dire : 'on va faire une concertation qui va permettre de voir ce que les gens veulent vraiment et de voir comment on peut ajuster le système en conséquence."
[lv] "C'est un jugement synthétique : extrêmement conflictuel. Extrêmement conflictuel. Un climat de discussion qu'on voit rarement dans les enceintes de concertations organisées par les pouvoirs publics."

[lvi] “Et après, il y avait tous ceux qui n’étaient pas invités... enfin, qui n’étaient pas présents à la concertation, et qu’on avait soit en bilatéral en échange, soit au téléphone... [...] Après, il y avait des insultes des menaces de mort, des gens qui essayaient de se suicider... »

[lvii] “[Tout cela] venait rendre une mesure difficile encore plus indigeste, et rendre la concertation extrêmement compliquées, parce que dans la même salle, vous aviez Touche pas à mon panneau solaire ! et Pâris Moratoglu, le PDG d’EDF-EN... [...] Vous ne pouvez pas mener une concertation sereine dans un cadre comme ça.”

[lviii] “Ils avaient invité à la fois des organismes professionnels, associations, ONG.... mais aussi des entreprises privées, comme Photowatt, Saint Gobain, qui étaient présentes *en tant que telles*, et pas en tant qu’organismes. Et on avait dit, là, déjà, y a maldonne, pace qu’on peut pas avoir des gens qui représentent une profession et d’autres qui représentent des intérêts privés ; évidemment on n’est pas sur la même longueur d’ondes. Par définition.”

[lix] “Dans l’atmosphère, c’était très curieux. Quand on reçoit les gens en bilatéral, quand on s’adresse à des gens du SER ou à des gens d’Hespul, on est quand même entre guillemets ‘entre gens bien éduqués’. Eux, ce n’est pas leur vie qui est en jeu. [...] Ils sont raisonnablement virulents, ils défendent leur point de vue, mais c’est pas des insultes, c’est pas ‘je me lève en plein milieu et je claque la porte’ ; ça reste très posé. Et souvent les dirigeants de PME, enfin d’entreprises d’une certaine taille, c’est pareils : ils gagnent dans les négociations des fois, et d’autres fois ils vont perdre, ils savent qu’ils faut qu’ils restent en bonne relation avec l’administration. Mais pendant la concertation, on avait quand même des gens qui eux n’étaient pas rodés à ce genre d’exercices, de liens avec l’administration, ou qui avaient mis tellement d’argent dedans que pour eux c’était devenu une question de survie de leur entreprise, ou de survie de leur bien personnel, qui eux étaient beaucoup plus virulents. [...] Il y avait quand même des petits acteurs qui eux avaient une entreprise de 10 personnes qui avaient réussi à se faire inviter pendant la concertation. Pour eux c’était une question de vie ou de mort, donc ils étaient un petit peu plus agressif.”

[lx] “On a dû faire 8 ou 9 réunions sur deux mois, on réunissait à chaque fois une centaine de personnes, enfin entre 50 et 100, dans une grande salle de Bercy, toutes les associations qui représentaient n’importe quoi, si petit que ce soit, venaient, et c’était un chœur de pleureuses face à des gens qui prenaient des notes.”

[lxi] “Alors pour dire, on était des amateurs à tout niveaux, en fait. Parce qu’on a tous été débordés par le dispositif.”

[lxii] “Il y en a qui ont vraiment un discours construit et des trucs à dire, mais pour beaucoup, ce sont des lobbyistes purs et durs et unidimensionnels qui ne démordent pas de leur trucs alors qu’il n’est pas solide du tout.”

[lxiii] “Vous avez une myriade d’acteurs [...] à qui on a donné [...] une tribune à la concertation, mais qui selon notre point de vue n’étaient pas forcément représentatifs du secteur, et qui représentaient parfois des intérêts très ciblé d’acteurs qui, par le jeux de la création d’une association, défendaient en fait leur propre intérêt, ce qui fait que tout ça a quand même été assez négatif.”

[lxiv] “On avait affaire, quand même, à cette époque là, à une filière PHOTOVOLTAÏQUE qui était pas organisée au niveau de sa représentation. Il n’y avait quasiment rien qui existait; il y avait Hespul, mais Hespul avait très mauvaise presse à l’époque, parce qu’ils passaient pour les écolo de service...”

[lxv] “Il y a beaucoup de choses qui ont été dites, propagées sans fondements, sans preuves, sur la collusion d’intérêts de certains adhérents du SER, par exemple avec les pouvoirs publics. Bon, EDF pour ne pas le nommer.”

[lxvi] “L’attitude d’EDF a été très mal accueillie par la profession photovoltaïque. Pour une raison qui est peut-être compréhensible, c’et que le segment où il y avait beaucoup de PME ne nous intéressait pas, donc finalement on n’était pas extrêmement solidaires. On ne pouvait pas demander aux dirigeants d’EDF-EN de défendre des investissements qui rapportaient 25% à leurs propriétaires sur les toits et qui globalement, en termes d’image, menaçaient toutes les filières renouvelables. [...] On a vécu notre attitude comme relativement équilibrées, mais c’est

vrai que, disons, le tissu de PME du photovoltaïque a eu l'impression que le gros s'en sortait bien et qu'il laissait les petits dans la difficulté. Donc on a vécu dans un malentendu qui a été un peu pénible pendant un moment."

[lxvii] "Il n'y a que cinq personnes [dans l'administration] qui bossent dessus : il y a un problème de compétences internes et de personnel pour piloter finement."

[lxviii] "Pourquoi des erreurs – parce qu'il faut bien appeler ça des erreurs – ont été faites par le passé, et ont encouragé la bulle ? C'est bien aussi par le manque de moyens mis en face des professionnels pour écrire des textes. Nos interlocuteurs, on les dénonce [sic] sur les doigts d'une main sur ce sujet. Et y compris l'administration centrale, donc ça fait pas beaucoup de gens. Pour écrire l'arrêté, il y avait une personne. Pour piloter ce truc, piloter les filières renouvelables, de manière générale, d'ailleurs, pour des filières avec des évolutions aussi dynamiques de coûts, il faut en face une administration réactive. Et, sans moyens, vous ne pouvez pas avoir d'administration réactive."

[lxix] "Mauvaise régulation, un État autiste qui n'a pas mis les moyens. Il faut voir qu'on n'avait une seule personne qui s'occupait du marché du solaire, et pas que de ça, à la DGEC [...] Et des arbitrages politiques qui ont tardé donc quand on dit 'l'arbitrage politique tarde', c'est à qui profite le crime, quoi..."

[lxx] "Nous avons du mal à savoir si, en cette affaire, le pilotage est vraiment assuré » « Nous ne pouvons que constater une gestion absolument erratique."

[lxxi] "Alors, ce qu'il faut voir, c'est que ces affaires là, qui coûtent 5 milliards d'euros aujourd'hui, ça concerne très peu de personne, et tout le monde s'en fout, en fait. Parce que le bureau énergie-climat de la DGEC qui a pris la décision, à l'époque en 2009, c'était trois personnes quoi... [...] et derrière, ils ont pris des décisions qui engageaient la collectivité pour plusieurs dizaines de milliards d'euros."

[lxxii] "Et alors c'est aussi un gros reproche que [je ferais au SER], c'est qu'ils ont perdu la crédibilité qu'on attendait d'eux. En tout cas moi, au bout d'un moment, je me disais : 'si je continue de les écouter, on va dans le mur.' Et ce n'est pas leur rôle. Alors ils ont un rôle de lobby, certes, mais moi je les trouvais particulièrement déraisonnables, et au bout d'un moment ils ne sont plus crédibles donc on ne les écoute plus." ; "[...] pendant toute cette phase un peu agitée, on avait l'impression qu'ils ne représentaient que les intérêts des développeurs [...]. Et essentiellement, les revendications des développeurs, c'est de faire le maximum de projets pour se mettre un maximum d'argent, et ce n'est pas du tout les mêmes que celles des développeurs industriels qui eux veulent moins de projets, mais qui utilisent leurs technologies à eux. Et ça, faire comprendre ça, y compris dans les hiérarchies, au cabinet, dire : 'attention, ceux que vous rencontrez, c'est des développeurs, donc pas des hommes d'affaires mais presque, c'est très peu d'emplois et c'est très peu de valeur ajoutées totale du proje et ce qui est important, c'est les toutes petites structures qu'il faut aider d'une façon ou d'une autre', ce n'est pas un message facile."

[lxxiii] "Ca a été une période extrêmement difficile et compliquée, parce qu'on était en interne au sein de contraintes extrêmement fortes ; entre le marteau et l'enclume, quoi parce qu'on est poussé par des adhérent qui, forcément, [ne veulent] pas une baisse, a fortiori pas un moratoire sur l'obligation d'achat, et par les pouvoirs publics qui ont une pression extrêmement forte pour maîtriser la dépense [...]"

[lxxiv] "Le Syndicat des Energies Renouvelables a été un peu dépassé par sa base. [...] Vu le nombre d'adhérents qu'ils avaient, [...] ils avaient du mal à tenir des positions très structurées et à les faire valider à la vitesse qu'il fallait par leurs adhérents. »

[lxxv] "Je pense que le monde du photovoltaïque n'a pas fait son travail, ils auraient dû réagir dès le départ et dire: 'attention, on est train de nous tendre un piège !'. Ils ont plongé dedans en se marrant, en se disant super, on a un tarif d'achat, enfin ! Sauf que le tarif d'achat, ça a duré deux ans..."

[lxxvi] "Dans le cadre du rapport budgétaire pour avis que j'ai remis pour l'énergie, sur 13 personnes auditionnés sur le photovoltaïque, j'ai reçu 13 avis différents ! Cette filière a, plus que jamais, besoin d'un pilote !"

[lxxvii] “La première réunion de la concertation au mois de décembre, on savait pas qui était autour de la table. Il y avait beaucoup de monde, il y avait 60 personnes ; on en connaissait quelques uns, mais c’était quand même pas... Je ne sais pas comment ils ont distribué les invitations, mais [...] la première parole que j’ai prise, c’était pour demander qu’on ait les emails de tout le monde. Parce qu’on avait un papier avec des noms, point à la ligne. Pas d’adresses, rien du tout. Donc j’ai vraiment insisté, et ça nous a permis de discuter, justement, d’avoir des échanges entre tout le monde.”

[lxxviii] “En mars 2011, on a été un certain nombre à dire que, finalement, on avait été victimes de notre division, victimes.... quasi-consentante et organisée par l’administration française au moment du rapport Charpin, qui avait organisé des réunions de la filière en prenant bien soin d’inviter un maximum de gens, avec – d’horizons extrêmement différents, qui ne s’étaient pas préparés à ce genre de réunions, dans une cacophonie totale, qui a permis à l’équipe de Charpin de dire : vous voyez, vous n’êtes pas d’accord entre vous, vous êtes dans des oppositions totales, et la règle – la direction, c’est celle-ci qu’il faut prendre. Et personne n’a été capable de réagir. Ca, c’était bien organisé. Et donc, on a été un certain nombre à dire : ça, il faut pas que ça recommence. On va avoir encore de nouvelles étapes, de nouveaux débats à franchir, il faut qu’on soit beaucoup plus organisés, et en tout cas préparés, même si on sait bien que dans cette filière comme dans bien d’autres, tout le monde ne peut pas être du même avis. A minima, d’identifier nos différences, d’identifier nos points d’accord, de mettre plutôt en avant les points d’accord que les points de désaccord, et d’en augmenter le nombre par plus de communication, plus d’échange, etc. et donc, c’est ce qu’on a fait au niveau des États généraux du solaire, en réunissant comme je disais plus d’une vingtaine d’organismes.”

[lxxix] “On s’est fait entubés.”

[lxxx] “Le constat qu’a fait tout le monde, c’est que [la concertation] était très décevante, puisqu’en fait toutes les décisions étaient prises avant.”

[lxxxi] “Le résultat, c’est que finalement, on a un peu l’impression que les dés étaient jetés dès le début.”

[lxxxii] “La pseudo-concertation était une chose schizophrénique. Ils n’ont pas écouté quoi que ce soit.”

[lxxxiii] “L’État ayant mal assuré la régulation, nous avons accepté le moratoire, mais nous n’avons pas été plus écoutés que les collectivités locales, les ONGs ou les parlementaires.”

[lxxxiv] “[C’était un] exercice dont la conclusion était écrite à l’avance, mais auquel il fallait participer, sauf si on avait tous décidé de ne pas venir, mais on avait tous espoir que ça ne serait pas écrit avant.” “Quand on est entré dans la première réunion de concertation, globalement, les deux tiers ou les trois quarts de ce qui a été conclu à la fin étaient déjà conclus.”

[lxxxv] “Exposer notre point de vue en si peu de temps, alors que nous avons eu l’impression de ne pas être entendus au cours des trois derniers mois, est une véritable gageure. »

[lxxxvi] “En clair, le Premier Ministre accepte de payer pour voir à hauteur de 500 MW, mais pas plus.”

[lxxxvii] “Mon administrateur a heureusement une formation d’ingénieur et il a pu me donner quelques explications, mais je reconnais que ce document est quelque peu... complexe. »

[lxxxviii] “L’arrêté du 4 mars 2011. Déjà, il faut avoir fait Polytechnique pour le comprendre ! Et à l’époque, on avait un polytechnicien [...], ça tombe bien, et il l’a compris !”

[lxxxix] “ [Pour comprendre] l’arrêté tarifaire tel qu’il est rédigé, il faut avoir un niveau en maths d’école d’ingénieur. Sinon, on ne peut pas l’appliquer. On ne peut pas le comprendre. C’est anti-démocratique. [...] Quand on pose la question au gens de la DGEC, ils disent : ‘oh ben nous on ne sait pas faire autrement, on ne sait faire que des équations.’ Enfin, c’est très révélateur de l’état d’esprit. L’installateur du quartier, il ne peut pas comprendre ce truc là ! C’est impossible, enfin culturellement !... Il n’y a pas de grille tarifaire, c’est un ensemble de signes kabbalistiques.”

[xc] “On a proposé [800 MW par an] au cabinet, et puis il y a eu une réunion au niveau du Premier Ministre où il y avait des gens de Bercy, des gens du cabinet de Nathalie Kosciuzko-Morizet [...], et ça a merdé, c’est 500. A un moment donné, la conseillère du Premier Ministre s’est énervée et a dit : ‘Mais non, vous n’êtes pas capables de me dire aujourd'hui combien ça coûte !’ – parce

qu'elle est revenue sur le passé en demandant combien il y en avait qui allait se réaliser. C'était à l'époque où on savait qu'il y en avait 4000 MW dans les tuyaux, qu'on en avait sorti 1000 ou 1500, mais on ne savait pas grosso modo combien il en restait et combien se ferait vraiment. Peut-être qu'on a mal communiqué pendant cette réunion sur les incertitudes... Et puis finalement, son raisonnement était : 'vous n'êtes pas capables de me dire combien ça coûte et vous voulez faire plus que les 500 MW par an qui étaient prévus initialement ? Mais vous rigolez, ça va nous exploser à la tronche !' donc on reste sur 500."

Chapter 5

Mutualising sunshine

"(Owing to the density of the magical field surrounding the disc, light itself moved at sub-sonic speeds; this interesting property was well utilized by the Sorca people of the Great Nef, for example, who over the centuries had constructed intricate and delicate dams, and valleys walled with polished silica, to catch the slow sunlight and sort of *store* it. The scintillating reservoirs of the Nef, overflowing after several weeks of uninterrupted sunlight, were a truly magnificent sight from the air and it is therefore unfortunate that Twoflower and Rincewind did not happen to glance in the direction.)"
Terry Pratchett—*The Colour of Magic*

How do feed-in tariffs set in motion? To what extent do they provide equipment for entrepreneurship and innovation in the photovoltaic sector? In the previous chapter, I have shown that, even though FITs had sparked the proliferation of a large diversity of photovoltaic projects, they could also be used as devices to close down the space for economic experimentation and political discussion. On the reverse, in this last chapter, I seek to explore in detail how they can serve as the basis for opening up new spaces for action.

Throughout the dissertation, I have stressed the tension at play within FITs as *agencements* between the constraints that frame action and the incentives that carry it away. How do these play out in the elaboration and realisation of a photovoltaic project? The case study presented here provides an example of the constitution of agencies through the use of feed-in tariffs for PV-generated electricity. It focuses on a mutualised photovoltaic project carried out by the "*Fermes de Figeac*", a rural cooperative in the Lot (Midi-Pyrénées, France). In 2008, having identified the feed-in tariff as an opportunity for the diversification of territorial resources and activities, the cooperative embarked upon the construction of a mutualised scattered photovoltaic plant. The project led to the installation of 109 photovoltaic systems on farm rooftops in the area and to the creation of a firm to orchestrate the development of the project and to ensure the maintenance of installations. The originality of the project stems from the fact that it is entirely mutualised as well as from its scope: it was and is likely to remain the largest mutualised photovoltaic project in France.

This project is of course not representative of the huge variety of photovoltaic projects that were developed in the late 2000s under the impulsion of feed-in tariffs. The objective of this chapter is not to account for the diversity of the ways in which FITs triggered action, but rather to analyse how they were seized and how they activated agencies in one specific case. In this view, several aspects make the *Fermes de Figeac*'s project particularly interesting.

First, the project was successfully carried out. Project leaders managed to use feed-in tariffs as a driver for innovation – not so much technological innovation as territorial and organisational innovation. Their initiative fell in line with the objectives of feed-in tariffs – it led to the installation of renewable electricity generation capacity – but it also carried these objectives away. By making feed-in tariffs a resource for territorial development, the project endowed them with effects that they were not intended to have.

The innovative character of the project lies in large part in the mutualisation of the opportunity provided by feed-in tariffs. Though the *Fermes de Figeac*'s project clearly took advantage of the high return rates guaranteed by FITs, it suggested an alternative way to redistribute the benefits of the incentives by relying on a cooperative and territorial approach. This innovation was made possible by the combination of the high investment security provided by feed-in tariffs with the flexibility and modularity of photovoltaic technologies. However, its realisation required a lot of work and the enrolment of many allies: the cooperative had to go through a series of trials and re-formatting to successfully become an actor in the renewable energy sector.

Of particular interest are the negotiations of the articulation of heterogeneity and homogeneity at the core of any mutualisation operation. Mutualising indeed implies choosing which characteristics to smooth out and which differences to keep at play. In the case of the project studied here, access to feed-in tariffs and to funding required a degree of standardisation of the resource, that is to say a levelling of individual situations, which enabled the constitution of the group of farmers as a distinct, individual economic actor. On the other hand, to make the most of the FIT opportunity and to convert it into a collective territorial resource, some of the differences between production sites and members of the group had to be activated.

This case study thus allows me to explore the material dimension of economic and political action and innovation as mediated by feed-in tariffs and photovoltaic technologies. It shows how feed-in tariffs and photovoltaic modules actively equipped a group to become a player on photovoltaic electricity markets (a role that FITs can be explicitly designed to play *or* not to play). To describe this project, I start with a description of its promoter, the cooperative SICASELI-Fermes de Figeac. The first section thus focuses on the history, organisation and values of the cooperative and on how the idea of a mutualised photovoltaic project emerged. The second part of the chapter is centred on the trajectory of the project. I first describe the constitution of the group behind the project, before analysing the trials and transformation that were necessary to turn farming roofs into photovoltaic plants. I then consider the specificities of the mutualised approach in terms of business model and in particular in the negotiation of funding.

Section 1 – The collective as a project: les *Fermes de Figeac*

1.1. A territorial cooperative

Les Fermes de Figeac is an agricultural supply cooperative based in Lacapelle-Marival, a small town east of the Causses regional natural park, in the Lot (46, Midi-Pyrénées). This rural, sparsely populated area is located between Périgord to the West and Aveyron to the East. The population of the largest town in the *département*, Cahors, amounts to a little over 20,000 (40,000 in the urban area). The membership of *Fermes de Figeac* does not extend all the way to Cahors: its *territory*[138] is limited to the north-east of the *département*.

This area is named *Ségala-Limargue* and does not map exactly onto any formal administrative area. It roughly corresponds to the part of the two geologically distinct areas of Ségala and Limargue that is situated in the Lot. In terms of administrative divisions, it includes the *cantons* of Figeac, Bagnac, Lacapelle-Marival, Latronquière and Sousceyrac. It is an area of small villages and hamlets, mostly populated by small cattle farmers and retired people enjoying the hilly and in some parts arid landscapes.

Farms are scattered but organised in dense, interwoven networks of cooperatives – given the small size of most farms, supply, sale, machines and materials are very often collectively owned. The *Fermes de Figeac* emerged in 1985 from this web of "solitary but solidary" (Interview 30) farmers, with the merger of the two small agricultural supply cooperatives of Lacapelle-Marival and Bagnac (Interview 40). It was then called *Coopérative Agricole du Ségala Limargue* (CASELI, a name which changed to SICASELI after a modification of legal status in 1991), affirming its territorial roots as core components of its identity. The recent change of name to "*Fermes de Figeac*" remains an affirmation of this strong territorial identity, even though some members from the parts of the sector furthest from Figeac consider it less representative of the actual territory of the cooperative (Interview 26). The cooperative's logo, which depicts a cow with a single mark in the shape of the *Ségala-Limargue* area, also reflects the close interdependence of the cooperative, the farmers and the territory.

1.2. A commitment to mutualisation and innovation as vectors for territorial development

1.2.1. The organisation of the Fermes de Figeac

The cooperative started as a small venture, with a staff of 20 that has steadily grown to reach 120 today (sicaseli.fr). Its membership, on the other hand, has tended to decline, reflecting the decrease in agricultural activity in the area. It now comprises 650

[138] I use "territory" and "territorial" to translate the French words "*territoire*" and "*territorial*". However, given the cooperative's commitment to these notions, it should be noted that the French terms convey a patrimonial aspect that goes beyond the mere spatial notion of a "territory".

members who are represented by an administrative board of 24 farmers and a president elected for three years.

The cooperative functions under the dual leadership of its executive director and its president, both considered crucial to its dynamism. The president was a member of the administrative board from the creation of the cooperative until his first election as president in 1997, and the executive director arrived in the early years of the CASELI. Judging from what interviewees said, they are appreciated for their openness, dynamism and entrepreneurship on the one hand, and for their ability to hold the group together and manage it in a transparent, collaborative manner on the other (Interviews 26, 29). To a certain extent, their management style embodies the values of the cooperative and can be seen as a way to enact them and to ensure they remain the common ground that unites the *Fermes de Figeac* members and projects.

1.2.2. A set of shared values and objectives

The values that bind the cooperative together – its ambition not to be a mere supplier of agricultural inputs but a "territorial cooperative" ("*une coopérative de territoire*") that supports farmers and their territory, its commitment to collective interests and management, its will to restrict its perimeter to a well-identified area – were determining from the start. They have been constantly renewed through its projects and regularly rewritten so as to maintain their relevance. They translate into an overarching vision from which a set of guiding principles is deducted. As the executive director stressed in an interview, they "always refer to it" as directions. These values thus serve as both a matrix for action and an actualisation of the cooperative's history.

> "Somehow, I think people return this image… It is not idyllic. We sometimes face difficulties, but it is true that – well, I think that we have managed to create a company with some sort of spirit. We have re-written our values, what it is that we stand for… It's not just business. We need business, but…" (Interview 32)[xci]

The objective of the *Fermes de Figeac* is to "contribute in the long run to promoting a high-added-value agriculture that manages the living and is innovative and open, in order to, from our territory, take part in a sustainable development for all" (sicaseli.fr).[xcii] This is a synthesis of the core values of the organisation, which are expressed as such:

- collective solidarity as the basis of the cooperative's action;
- the notion that there is no progress without respect for humans;
- the importance of maintaining action over time and of transmission;
- respect for the living and passion for the territory as the basis of professionalism;
- openness to others and attention paid to everyone as guarantees of performance;
- innovation as a necessity to keep local know-how and culture alive.[xciii]

By striving to implement and maintain these values, the *Fermes de Figeac* articulate collective action, territory and innovation as mutually dependent. But these are not considered as abstract, stable entities: much to the contrary, the organisation of the *Fermes de Figeac* and their projects show that their members consider their values, their territory and their collective as requiring constant attention and maintenance.

Their commitment to territorial, cooperative and innovative action is in fact very material and permanently re-enacted.

1.2.3. A cooperative and a territory

This conception of values as needing to be regularly reaffirmed, re-written and re-enacted has probably been crucial in keeping the cooperative closely bound. The president's approach to management seems informed by the belief that the cooperative dynamic can never be taken for granted, and instead requires time and dedicated work. The president of *Fermes de Figeac* thus explained how he conceived of his role at the end of our interview:

> "I don't really like to push myself forward, I prefer the group to… well, to put people in charge. I can see it at the level of the cooperative's council: it's not the one who's talking, while he is talking, everyone [shuts up]. I wouldn't like it that way. So, I will rather let people talk. And we take time, too. Time matters, once again. When a project does not reach unanimity, it means that something is wrong with it. So we work it through and through, we try to have as much adhesion as possible. I think it is a way to work the collective: everyone in their place." (Interview 32)[xciv]

Maintaining shared interests and a common purpose is critical for the smooth running of a cooperative structure, so the fact that it seems that "people are attached to their business" (Interview 32) is likely to have played an important part in the success of many projects of the *Fermes de Figeac*.

The cooperative's approach to the territory is somewhat similar, in that it considers it as a great potential resource that requires constant care and work to be exploited and maintained. And, crucially, the *Fermes de Figeac* depend on their territory as much as they depend on the good understanding among their members. The territory constitutes both "a space of resources" and "a space of partnerships"; it is an ally for innovation and development as long as these resources and partnerships are correctly harvested (Olivier, 2013). Cooperation fosters innovation, they argue:

> "[…] looking back, we have in the end done nothing but given meaning to the spirit of cooperation, which consists in finding together profits that one did not imagine alone." (Olivier, 2013)[xcv]

Most crucially, in an ever-changing world where adaptation is a necessity, the ability to innovate is essential to the territory, to its agriculture *and* to the cooperative (which, after all, exists for the territory and its agriculture). It is a conviction of the *Fermes de Figeac* that they can only thrive through the type of collective action made possible by a sense of belonging to a same territory:

> "We need to adapt continuously. Only through mutualisation will we manage to do it sustainably. The territory unites us once and for all." (Olivier, 2013)[xcvi]

Because of its constitutive choice of being rooted in an area, the *Fermes de Figeac* have not extended, at least not in perimeter or membership. At a time when small cooperatives tend to regroup and merge with larger structures, the *Fermes de Figeac* thus stand out in their firm belief that maintaining locally sourced and steered economic activity is an asset for the region.

1.3. On the lookout for new resources and activities

Since the cooperative is "locked into a territory and willingly so" (Interview 40),[xcvii] its prospects are closely tied to those of the region: the Sicaseli conceives of its activity as inextricably linked to that of the territory, so there is no escape if the area dwindles. Its only path to development lies in the reinforcement of agricultural activity and, most importantly perhaps, in the diversification of territorial resources, competences and projects.

This commitment to maintain and develop the territory and its specificities transpires through all the projects of the *Fermes de Figeac*. The cooperative is conceived as a device for the support and renewal of a type of agriculture, the importance of which goes far beyond its mere economic impact. In such a rural region, agriculture remains a crucial basis for territorial activity and dynamism; on top of this, it shapes the landscape, contributing to its conservation and attractiveness.

> "Agriculture is obviously an essential actor in the landscape. It is interesting to show that the landscape is the result of human construction and that we need an active rural world to make it live."(Olivier, 2013)[xcviii]
>
> "Part of what is at stake with agriculture in the area is the conservation of rural activity, as the maintenance of the landscape depends on it." (Interview 32)[xcix]

And, of course, since the cooperative's members and shareholders are farmers, the *Fermes de Figeac* are constitutively very much concerned by the future of agriculture.

1.3.1. The decline of agricultural activity

According to its members and staff, the cooperative depends not only on the persistence of agricultural activity in the sector, but also on its ability to develop innovative projects that fit what society expects. At least, they say, if the cooperative as a "*structure de proximité"* disappears, its projects will live on, as long as they are sufficiently rooted in the territory and appropriated by those who live there.

> "The strategy of our administrative board is to keep a local structure, close to its members. I don't know if we are going to make it. But what is certain is that we will not make it unless we launch into a strategy for diversification, for the creation of new activities directed towards what society looks for: sustainable development, local products, local economy…" (Interview 32)[c]
>
> "Today, we cannot be sure that we will not [be absorbed by a larger organisation]. So we put all of our energy in trying to anchor in the territory. Even if we get absorbed, we know that no matter what, the territorial projects are not going to disappear." (Interview 20)[ci]

This concern for the future of the territory and its agricultural fabric led the *Fermes de Figeac* to commission a regional agricultural forecast to 2020 to support the definition of its strategy. Carried out in 2008, the study on "The agriculture of Ségala Limargues in 2020" (L'Agriculture du Ségala Limargues en 2020, Sol et Civilisation, 2008) considered three scenarios, pointing out that agricultural activity in the area was set to decline – which confirmed the diagnosis of those living there.

The region indeed faces several challenges. First, its agricultural fabric, mainly composed of small-scale cattle farms living off a not-so-rich soil, is confronted to heightened competition from more productive regions, to the dependence of farming on large retailers, and to the increasing volatility of cereal and raw material prices.

> "The whole livestock sector, bovine, ovine too, even pork… we're doing *badly*." (Interview 27)[cii]
>
> "The difficulty is that on all quantity markets, milk, meat, we're competing with all of Europe; on the same prices, we do not have the same constraints." (Interview 32)[ciii]
>
> "We do not really have any comparative advantage on our territory; we're in semi-moutainous areas. Compared to the Parisian area, compared to Brittany, where the sector is very organised, well... we weigh little." (Interview 20)[civ]

Partly as a consequence of increasing difficulties in maintaining a profitable agriculture, the number of farmers has been declining. This trend is set to continue: the overall population of farmers is "growing old, from what we heard. That is, many are going to retire and there won't be a lot of people to take over the farms" (Interview 28).[cv] The number of farmers in the area is indeed expected to decrease from 650 today to 350 by 2020 (Interview 40). The decline in agriculture goes hand in hand with an overall decline in population and activity in the area, which is often pointed out as a serious issue.

> "There's a local fabric that you need to build, if we start disintegrating it everywhere… Today, in Latronquière there is only one grocery store left. I think it is hard, but if everybody runs away… after a while, everybody is going to go." (Interview 26)[cvi]
>
> "The Sicaseli, as opposed to others, has a territory. […] We work in the area. The number of farmers is decreasing by 20-30% a year, so the agricultural market, the supply activity of the cooperative, will keep on decreasing. So we need to find other sources of income." (Interview 29)[cvii]

The cooperative takes the risk of the extinction of agricultural activity seriously; as the *Fermes de Figeac*'s website points out on a page focused on its "ambition":

> "If nothing is done, agriculture is bound to fade away from the territory, and with it not only an important economic activity (about 40 millions € turnover produced by farms), but also all the amenities (water quality, open landscape, green energy production and carbon capture by grasslands)."[cviii]

The conclusion they draw from the three scenarios is that they "have only one way out, and that it is to change directions. Changing directions, well, this is imagining all that is possible to regarding financial resources – we have sun, we have wind, we have water, we have biodiversity…" (Interview 40).[cix]

The strategy of the *Fermes de Figeac* is thus clear: new resources, new sources of values, new forms of organisation need to be identified, developed and exploited – for the farmers individually, for the territory, for the cooperative, for the land.

> "We must find new added value for the products, and other ways to organise, or other resources, so as to maintain activity here. Because without activities and without people to look after the land, after a while the land… loses its interest." (Interview 32)[cx]

1.3.2. A need for diversification

The results of the forecast may have reinforced this approach, but it was, in fact, no change of direction for the cooperative. Since its creation, *the Fermes de Figeac*have sought to expand their range of expertise and competences, so as to support and develop the territory. As they claim:

> "The Sicaseli developed along with its territory, making the most of its progress and supporting it through a continuous search for innovations" (sicaseli.fr).[cxi]

Being just another supplier was never the objective of the Sicaseli, and it sought ways to diversify early on.

> "And the more we'll develop this kind of things, the more work there will be in area. That is the objective of the cooperative. To bring more money to the territory, and to provide work for more and more people. […] If we're just selling stuff… well, enough people are doing that already." (Interview 29)[cxii]

Supply remains the Sicaseli's main activity and provides 55% of its income. On top of this, the cooperative has developed along several streams of activity: direct sales, consulting, energy, building material supply, and service provision. This diversification started with the opening of a "Gamm Vert" store in 1986 (several others followed).[139] In 2000, the Sicaseli also developed a service provision branch with the creation of a CUMA (*Coopérative d'utilisation du matériel agricole*) to purchase innovative equipment. The cooperative is in fact constantly on the watch for potential paths to diversification, because it considers that finding new resources is a necessity.

> "In a way, we have to look for new activities, and that was the original idea that led our cooperative into organising an active watch over new businesses, over energy, over bio-prestations…" (Interview 20)[cxiii]

Fermes de Figeac's members and staff thus present curiosity as a crucial driver of their activity. The partnerships and networks they have constituted help them watching out for emerging trends and innovative projects. To add to this, they also frequently organise travels both abroad and within France, take part in conferences and networks, and keep watch of the evolutions on some key topics, such as energy.

> "We have always had this strategy: we are curious. So we travel a lot. We have been to Brazil, to Germany, to Japan, to Poland, to Italy, to Tunisia… We have been all over, every other year we organise a trip. We look for information." (Interview 40)[cxiv]
>
> "We try to absorb the positive, to attempt to make something new out of it." (Interview 26)[cxv]

This diversification within a clear direction has led the cooperative to create ties with a range of local cooperatives and businesses as well as with local governments and agencies, thereby strengthening its public image of a cooperative focused on the promotion of territorial agricultural activity. Its action over the past decades has established the Sicaseli as a credible and reliable economic actor – which has also been an asset when starting new projects.

> "When you have scientific proofs, or paperwork, you have to work with reliable people. You work with the *Agence de l'eau*… And now, we have started to set a foot everywhere… Then you have references, then you bring it all on a plate… sometimes it works." (Interview 29)[cxvi]

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[139] Gamm Vert is a French store franchise specialised in gardening tools and local food products. It was created by the *Union nationale des coopératives agricoles* in 1977.

This attention to potential new activities is supposed to help identify relevant long-term trends and potential new resources to be exploited, and thus to give ideas of the strategic directions to consider. On the other hand, once these trends have been identified, the Sicaseli keeps a watch on their evolution through a number of lenses (information from various networks and partners, policy watch...) so as not to miss any opportunity to make the most of a potential resource. In short, the "curiosity" of the cooperative aims at articulating a long-term perspective in a changing environment to build and maintain a capacity to react to any opportunity that may serve their strategy.

> "We work in the long-term. We need to give meaning to the long term. I think that is important. Even if, since everything is always moving, reactivity comes into play. You need to be ready when it's right, but you need directions and you need a long-term perspective." (Interview 32)[cxvii]

1.3. The origins of the photovoltaic project

The photovoltaic project directly stems from this approach. From what they say, the Sicaseli had long identified energy (and especially renewable energy) as a potentially interesting territorial resource, and they were paying attention to ways in which they could benefit from the emergence of renewable energy since the early 2000s.

> "We have identified for… of, well over ten years, the issue of energy as one at the heart of our preoccupations, and as something we could turn into an asset. So, without thinking about solar in particular, we created a small team to follow the topic and have organised several trips." (Interview 32)[cxviii]

1.4.1. Discovering photovoltaics

In addition to following the evolution of renewable energy in policy and society, the *Fermes de Figeac* visited several sites where innovative rural renewable energy models had been developed in France and abroad. As far as photovoltaics were concerned, the turning point was a visit to Fribourg in 2006 (Tenesol & Sicaseli, 2010). The executive director recalls:

> "And one day, I went to a conference, I was in Fribourg and I saw all these photovoltaic roofs, I saw all that Freiburg was doing in its sustainable development approach. I went back there with my president, telling him, there is something going on here. And then we travelled there with the administrative board." (Interview 40)[cxix]

Back from a visit organised in collaboration with ADEME, the *Fermes de Figeac* decided to experiment with solar energy. They started by installing a photovoltaic system on the roof of one of their stores. It was put into service in 2008. Though they consider it far from perfect, this project was a first experience with photovoltaics and introduced them to the sector and the challenges of photovoltaic project development. As such, it constituted a stepping stone for going further in this direction (Interview 32).

1.4.2. Mutualised photovoltaics as an option

Another determining encounter was that of the SA4R, a cattle-breeder cooperative in neighbouring Aveyron. The SA4R was a pioneer in cooperative rural photovoltaics. In 2008, they had already embarked on the development of a collective photovoltaic project and had installed photovoltaic systems on farm roofs. The project was divided into several sets of about 20 installations each, for which all the administrative work and benefits were mutualised. This business model, which provided a way to reap the benefits from solar power, inspired the *Fermes de Figeac*.

Indeed, having identified solar power as a potential resource, the *Fermes de Figeac* were looking for ways to harvest it to the benefit of the farmers and the territory. The high feed-in tariffs for photovoltaic power had not gone unnoticed: by the late 2000s, there was surely profit to be made from sunshine. Offers and phone calls from various solicitors seeking to rent farmers' roofs to install photovoltaic systems or offering to build barns for free as long as they could use them for photovoltaic project development only confirmed that rural photovoltaics were a profitable business. Several members of the *Fermes de Figeac* were thus keen on developing a photovoltaic project. The cooperative, seeing in it a great opportunity, wanted to distribute this resource widely and make sure that all kinds of farmers could benefit from it.

The issue was thus to seize the photovoltaic opportunity (which was likely to be fleeting) in a way suited to the cooperative's values and commitment to territorial development. The SA4R project provided an example of a business model that took advantage of the FIT-enhanced profitability of photovoltaic electricity to mutualise it. The executive director recalls:

> "We had a garden store, we installed a photovoltaic roof on it, doing a more or less good job. […] But we think there is something here. And then, the opportunity, with the 60c tariff. We think, oh, heck this is worth suggesting to our farmers. The first few months, we seek an angle to sell our roofs, and then as we have a cooperative strategy and we move around, one day we were in Aveyron, and we saw a model set up by people there – and then, it clicked: here's what we need." (Interview 40)[cxx]

The photovoltaic project thus originates from a convergence of interests for photovoltaics among the *Fermes de Figeac* members and staff. Canvassing by photovoltaic developers had sparked the interest of many farmers of the sector, and some were considering installing photovoltaic panels on their roofs. The visits of *Fermes de Figeac* to Fribourg and to the SA4R, as well as their first experience of installing a photovoltaic roof, convinced the cooperative's board and staff that photovoltaic electricity was a resource worth exploring, especially as by 2008, feed-in tariffs for BIPV promised considerable returns on investment. While the members of the board were discussing the possibility to embark on a photovoltaic project, one of the *Ferme de Figeac* employees, Laurent Causse, became enthusiastic about the idea and strongly pushed for it within the cooperative (and in fact ended up redefining his own job). These dynamics, as many interviewees recalled, resulted in a collective reflection on how the *Fermes de Figeac* could profit from the opportunity as a group while also opening it up for as many individual farmers as possible.

> "From the moment when we start talking about photovoltaic roofs, and when you have a project at the political level with a tariff and a profitability threshold, all at once, it catches your interest. And, then, lots of companies were set up. Automatically, everyone

with a large roof was called upon. We got phone calls, or things like: you own a roof, would you like to rent it, here and there. Hence the collective idea: why wouldn't we do it ourselves?" (Interview 27)[cxxi]

"Some companies did door-to-door sales, offering either roof rentals, or the construction of photovoltaic-covered buildings, with the building belonging to us after 25 or 30 years. So that set me thinking. I thought, well, if people are interested in renting my roof or in building me something for free, there must be something behind it… So one day, we had a meeting at the Sicaseli, and then… That's how the project started: at the first discussion, yes, that could be interesting." (Interview 31)[cxxii]

"I don't know how it happened, but a few days later, a company based in Bordeaux contacted me […] to rent my roofs. Then once again, I asked them to conduct a feasibility study, and the offered to rent all of my roofs for 8 euros/m^2. It did look interesting: you rent roofs and that's all you have to do. So I was ready for that, because I did not have to invest anything. But something bugged me all the same, a little bit: I did not know them, I did not know where I was heading, I was by myself, a tiny individual in front of a company I knew nothing about." (Interview 30)[cxxiii]

Section 2 – The project as a collective: turning photovoltaics into a collectively exploited resource

The original idea of the *Fermes de Figeac* implied the use of feed-in tariffs as devices for regional development and mutualisation – which was not necessarily what they had been intended for, even though they allowed it.[140] How could a photovoltaic project be designed to make use of FITs so as to serve the *Fermes de Figeac* values and objectives?

Along the course of its development into an actual photovoltaic park, the *Fermes de Figeac's* idea went through a series of trials. The fate of the project hinged on three related challenges. First, the leaders of the project had to make sure that the group stuck together. Second, the group and beyond it the "territory" (all the non-humans that were also involved in the project) also had to be "transformed" and reframed as photovoltaic electricity producers. The trials thus involved a "formatting" of those who took part in the project to enable them to become photovoltaic electricity producers. Last, it was crucial to maintain the project's financial and legal viability and profitability throughout. A failure in any of these three dimensions could make the project collapse.

Following the chronology of the project's realisation, the trials it went through thus fall into three categories: (1) the constitution of the group that would carry out the project; (2) the reframing of roofs, farms, farmers, and the cooperative to endow them with an agency on photovoltaic markets; (3) the challenges posed by the unprecedented scale and nature of the project. The 'business model', first drafted very early on, was fleshed out and to an extent altered as the project was displaced, enrolling an increasing variety of actors, interests and competences (Coutouzis & Latour, 1986; Doganova, 2009; Doganova & Karnøe, 2014).

[140] As mentioned in chapter 3, in the countries from which the FIT system originated (namely Denmark and Germany), many renewable energy projects were community-based, and one of the qualities of FITs is their ability to support diverse, small-scale and decentralized projects. However, this dimension was not explicitly stressed when designing French FITs.

2.1. Mutualising the opportunity of feed-in tariffs for PV-generated electricity

As shown above, the initial idea of the *Fermes de Figeac* emerged from a convergence of interests and opportunities, including a conviction that energy could and should provide a new resource for the territory, high feed-in-tariffs that (albeit incidentally) happened to be particularly attractive for agricultural photovoltaics, and the inspiration provided by the encounter with another cooperative already involved in a similar project. These factors suggested that it was possible not only to seize the photovoltaic opportunity (many farmers had already reached this conclusion), but to do so "the *Fermes de Figeac*'s way" – that is, using it as an opportunity for territorial and cooperative innovation.

2.1.1. A scattered photovoltaic plant

The objective of the *Fermes de Figeac* was to exploit the solar resource available in the Ségala-Limargues area that feed-in tariffs for PV-generated electricity had suddenly made attractive. But the *Fermes de Figeac* also wanted as many farmers as possible and, crucially, the territory itself to benefit from it: farmers should exploit this resource themselves, lest other investors seize it.

Following the example of the SA4R, the *Fermes de Figeac* opted for a mutualised scattered photovoltaic park – a model made possible by FIT market *agencements*. Access to feed-in-tariffs is not determined by where the photovoltaic electricity is generated, but by who sells the electricity, that is to say, who has invested in the installation that generates it. In the project of the *Fermes de Figeac*, photovoltaic systems would be installed on buildings owned by several farmers and often situated miles apart, covering a large area, but would all be owned and operated by a single entity.

At the time, business models based on the disconnection of the operation of photovoltaic systems (i.e. access to the feed-in-tariffs) from the ownership of the surface on which they are installed (i.e. access to the resource and, often, to the BIPV premium) were thriving as a means to overcome the scarcity of one key asset for making photovoltaics profitable at the time: well-exposed buildings surfaces. The *Fermes de Figeac*, however, had almost direct access to plenty of large rooftops located in a sunny area. The originality of their model lies in the mutualisation of both this architectural resource and the legal entity responsible for installing, owning and operating the photovoltaic systems. This entity was to be constituted by the association of all those "bringing in" roofs. As a result, only those with direct interest and assets in the project would be involved in investments and decisions, each contributing and earning in proportion to the size of the installation on their roof. Annexes 7 to 9 give an overview of the project material, financial and organisational structure.

In such a model, the scattered structure of the project is channelled into a centralised but collectively owned organisation. In this way, the project can span the whole territory of the cooperative and involve a large number and variety of farmers, while retaining its unity and benefiting from the concentration of competencies, credibility and decision-making capacity provided by the *Fermes de Figeac*.

> "So, when we proposed this model, the objective was to gather as many persons people as possible, not in order to develop the largest project, but mostly to allow all types of farmers to benefit from it, not just the big ones. Which means people who did not necessarily have the time or ability to analyse a photovoltaic cost estimate – it is not complicated, but to understand the cost estimate for a photovoltaic installation on a building, if you want to make sure not to be conned, you need a minimum of information." (Interview 20)[cxxiv]

The crucial challenge, then, was to combine the collective, mutualised dimension of the project with the reactivity and competence of a small team dedicated to taking the project forward. The collective dimension had to remain an asset and never become a burden; the concentration of skills and decision-making capacities driving the project had to remain in close connection with the pool of participants.

2.1.2. A relatively risky project

The success of the initiative hinged on the preservation of this fragile balance, and increasingly so as it moved forward. Even for an experienced cooperative like the *Fermes de Figeac*, this would be a challenge. Electricity production was a largely uncharted territory for them, and photovoltaics were an emerging market and a relatively little tested technology. Going mutual involved a rather large-scale venture: all in all, the risk was significant. Failure would severely damage the cooperative's image and credibility, not to mention financial risks. There were hesitations at first, some of which persisted until project completion.

Still, preliminary projections suggested that if it worked, the project would yield as profits as high as those carried out by private developers – maybe more – and would do so in line with the values of the *Fermes de Figeac*, thereby re-shaping the possibilities offered by feed-in tariffs.

> "We got a bit scared, because we soon realised that with such financial commitments, we were putting the structure at risk. We thought, if it works, it will be alright, if it does not… But we thought, we should go for it anyway. We should go for it, and we can do so only by adopting a collective approach and setting political rules from the start." (Interview 32)[cxxv]

Driven by Laurent Causse's enthusiasm, which quickly spilled over to the president of the *Fermes de Figeac*, as well as by the interest of several members of the administrative council, the cooperative decided to take the risk and set off in the adventure.

> "To be honest, Laurent got us involved. He got passionate about it and drew us in. But the president got passionate about it too, he believed in it. As for myself… I was in but I curbed [the enthusiasm] a little because I was afraid we would crack under the astronomic sums involved. I backed the project but I was cautious, I incited for caution. And since a majority of the farmers in the administrative council who owned roofs thought the project interesting, they pushed us forward." (Interview 40)[cxxvi]
>
> "First, within the cooperative, it was debated. […] I must confess that it was rather tense, because I really believed in it, so I fought to do it, but everyone did not agree." (Interview 20)[cxxvii]
>
> "[Laurent Causse] really hung on to give birth to the project.[…] There were not many who did not want to go for it, but you still needed a firm hand, someone who would not give up in front of constraints. And he was the right person." (Interview 33)[cxxviii]

"You have to be bold. I think at some point you need some nerve. But then, those in the administrative council were dynamic people, and there you go. You need to try. You move forward and then… you learn." (Interview 30)[cxxix]

2.1.3. Recruiting roof owners

After a couple of discussions in administrative council meetings, the idea was considered promising. The next step was to assess the feasibility and potential of the project: would it spark the interest of members of the Sicaseli? If so, how many of them would join in? What would it imply for the project's viability and scope? The number of participants would not only determine the viability and size of the project, but also the availability and quality of the resource, since each participant came with one or several rooftops with specific radiative characteristics.

2.1.3.1. Solar enthusiasm

As Laurent Causse pointed out, the objective was to involve a large number of people. To survey potential participants, the *Fermes de Figeac* relied on traditional methods: it sent letters presenting the project to all its members, inviting them to attend information meetings in March 2008. The announcement was met with unexpected enthusiasm; participants in the first meeting largely outnumbered the Sicaseli's expectations based on usual attendance to similar events.

> "It is quite surprising actually; we mentioned it once or twice during administrative council meetings, and then several say: that's not bad, that's not bad. We think the project may trigger interest, and we send out a call. And we invite everyone in a village hall. We expected 50 people, 350 attended. That was a big surprise. […] When we hold a meeting today about agricultural development, we send five reminders, and 20 people attend. And here, what happens? The same farmers, we send them a piece of paper about photovoltaic roofs, and 350 of them attend." (Interview 40)[cxxx]
>
> "They launched a meeting, inviting everyone. Every farmer from around here; all the members of the cooperative. They sent a letter, kind of the same as the one we received today […] asking if anyone was interested. They did that in a small venue, it was full, we could not even close the door, people were so interested. […] I would never have thought people would be that interested in solar power." (Interview 28)[cxxxi]

For sure, the model suggested by the *Fermes de Figeac* was likely to attract interest: it provided access to a very attractive investment while implying very little work. A cooperative structure these farmers knew and trusted would take on all the administrative and technical responsibilities as well as the main part of the financial risk. As Laurent Causse stresses:

> "We really did not expect such a feedback from farmers. We had a very strong feedback because, first, people trusted the cooperative, and we offered them a turnkey product. They trusted us and they had nothing to do." (Interview 20)[cxxxii]

Indeed, the model *Fermes de Figeac* proposed considerably facilitated investment in photovoltaics. Mutualisation is reassuring for people who are used to dealing with cooperatives; it provides strength and security when an individual investor would be left alone to deal with potential problems, and, in the form imagined by the Sicaseli, it considerably reduced the amount to invest by pooling resources and negotiating a large loan. Though most participants were well aware of the opportunity that feed-in tariffs for PV-generated electricity represented, it seems that they would have considered the matter twice had they been on their own. Their trust in the cooperative and the many guarantees and advantages the project promised were key to trigger their decision to invest in photovoltaic electricity generation – without it, it is likely that many would not have jumped in.

> "[Without the *Fermes de Figeac*'s project], not many would have tried. Some. Not even 10%. Maybe 2-3%. That's all. I don't know. For me, I don't know. That tickled me, sure, but… […] I adhered right away to this group idea and all […] I'm not sure I would have taken the plunge. Or, if I had, I wonder if it would not have been too late. Because you had to react!" (Interview 27)[cxxxiii]
>
> "Not my own, no. No, because… Some went for it on their own, and I can see it, when they have problems with ERDF, either with grid connections or with bills payment and all, when it's just one guy… Whereas in our case, as we're a group, well, if one does not get paid, if there is a 6-month delay for two or three files, the rest comes in. It offsets. It's a whole. And such projects, going at it alone… We had between 1200 and 1300 m^2… And the investment banks may not have followed in the first place. And well… Whereas when you have only 20% to pay as in this case, that's ok." (Interview 29)[cxxxiv]
>
> "So I was in from the start, because I thought – on my own I would not have done it, together with others, I thought, we limit risks, so I said, why not. […] But it was mainly because it was a group. On my own, as I said, I would not have done it, because there were high risks involved. Here, risks are less important, and the project as a whole with a large area implied that we were able to obtain commitments from suppliers that we would not have obtained on our own. That as my first motivation." (Interview 31)[cxxxv]
>
> "From the start, I thought, there is something to do here. I wanted to do it, and I even had cost estimates made. But when I saw the cost estimates, I got scared. Because going at it alone… So I did not feel up to it, because it represented enormous amounts." (Interview 30)[cxxxvi]
>
> "Well, there were 110 projects here. There are more technically, but there were 110 projects, or 109 farmers. Of these 109, objectively, if they had gone at it alone, only about fifteen would have done it." (Interview 32)[cxxxvii]
>
> "Many farmers could not obtain funds directly. Many would have given up if they had gone for it alone." (Interview 24)[cxxxviii]

However, there is also something specific to photovoltaics or maybe rather to photovoltaic feed-in tariffs about this enthusiasm. Jean-Michel Villiot, who worked for Tenesol at the time, recalls a similarly unexpected crowd attending an information meeting on photovoltaics in Toulouse in February 2008:

> "It was an association of 2000 engineers from the region, and usually 10-15 people attended [their meetings]. So the guy tells me, there will probably be about fifteen of us, something like that. I tell him, be careful, it's a hot topic, there could be more. […] So the meeting that was first supposed to take place in the small Tenesol office, where we could have 30 people, was moved to an amphitheatre in Blagnac, and in the end we moved it back to Tenesol and rented a big tent. And we had 230 people." (Interview 33)[cxxxix]

With BIPV feed-in tariffs nearing 60c/kWh, the opportunity was too blatant for people not to rush in, if only to consider it.

2.1.3.2. Consolidating the project

Riding the wave, the *Fermes de Figeac* worked to constitute the group that would be involved in their project. This involved evaluating its dimension, geography and potential while organising it. In a project like this, the material structure and the legal, social and financial organisation of the group shape each other. Available roofs, their surface, location and exposure to sunshine – i.e. the resource – first depend on who decides to take part in the project. In turn, since shareholders contribute in proportion to the size of "their" installation, the distribution of roofs not only determines the overall expected potential and cost of the project, but also to an extent influences the structure of the company (size, social capital necessary, relationship with financial and technical partners…). Last, legal, technical and financial factors related to the organisation of the company and to the terms of its relationships with partners (photovoltaic module suppliers and installers, bankers, state officials) or to the situations of specific candidates (ownership of the building, financial means…) influenced the ability of some farmers to take part in the project.

Between April and July 2008, several meetings were held to consolidate the project, recruit and inform participants, conduct preliminary technical studies, assess organisational options and pick one among them. Detailed knowledge of each roof potentially included in the project was crucial for these operations. To obtain it, those willing to take part in the project were asked to fill in and return a *"Déclaration d'intention"* before 30 June 2008.

This document listed criteria for the pre-selection of roofs by candidates: south-facing by ± 40°, a slope of at least 20%, a minimal area of 150 m^2 around the building, no shadow. It made an inventory of the characteristics of buildings that were deemed relevant for the project: technical and architectural characteristics (dimensions, slope, type of roof cover, type of frame…), administrative details (information related to the cadastral plan, municipality) and information in relation to the electric grid (distance between the roof and the electricity meter, distance between the meter and the transformer, power of the meter, distance between the meter and the post, situation within the grid). In addition, candidates were asked to draw sketches of the buildings indicating the the North, the location of the buildings proposed, the distance between them, road accesses and distance from the nearest EDF post. The Sicaseli received 270 of these, and a total of 500 roofs were proposed for the project (Tenesol & Sicaseli, 2010).

2.1.4. A new actor in territorial renewable energy: SAS Ségala Agriculture et Energie Solaire

By the end of July, with the help of a legal consultancy, most organisational issues had been settled. It was decided that the entity in charge of the project would be a "*Société à actions simplifiées*" (SAS).

> "So, options were an SARL, an SA, an SAS. Given their numbers – they are, I do not remember how many, about 130-140 of them – an SARL was too complicated. And as the project was carried by the cooperative, they wanted it to work a bit like a cooperative. An SAS, with a president, an administrative board, it sort of works in the same way. So they liked it right away. For all that, they did not want to create a cooperative, because there were very important investments involved and those would come back to the owner for free through the emphyteutic leases. So that's the cooperative-like functioning, with a president and an administrative board, that they liked." (Interview 24)[cxl]

Each participant in the venture would hold shares in the company. All were asked to contribute an initial sum of 500 € to constitute the initial share capital. Decisions would be made by an administrative council comprising twelve members representative of the diversity of those involved: farmers from different parts of the region, with farms of different types and sizes, members and non-members of the administrative council of the *Fermes de Figeac*. The designation of administrative council members was an important step, as the president of the cooperative recalls.

> "Transparency, on the one hand, through general meetings and an administrative council. Even if it was a kind of co-optation in the beginning, we picked 12 persons, interested in these issues, diversified in terms of geographical distribution and origins – all were not administrators of the *Fermes de Figeac*, they even were a minority." (Interview 32)[cxli]

The *Fermes de Figeac* as well would own shares and be represented by their executive director in the administrative council. A convention was to be signed between the two structures, under which staff from the *Fermes de Figeac* could be employed by the SAS. The ties between the two structures would be further reinforced by the fact that they would have the same president. The SAS would thus be a distinct entity, with its own members and rules, but remain closely tied to the *Fermes de Figeac*.

The founding general meeting that created *SAS Ségala Agriculture et Energie Solaire* (SAS SAES) was convoked on July 28th, 2008. In the process leading to the creation of the firm, the project was delineated and its technical feasibility and potential were assessed (which was not possible until prospective participants had been identified).

The SAS SAES, whose social object is "the generation of electricity from photovoltaic sources for commercialisation", was created with an initial social capital of 617 shares worth 100 € each. They were owned by 132 shareholders from 121 farms, bringing in 280 roofs for a total surface of 84,000 m^2 (so the initial enthusiasm had already been filtered). On the basis of preliminary technical studies, it was anticipated that 58,000 m^2 of photovoltaic panels corresponding to 6.5 MW in capacity would be installed for an expected total cost of 41 million euros.

The SAS SAES articles of association tie share ownership to the buildings equipped with the photovoltaic systems:

> "[…] It is specified that only people attached to a building on which the SAS SAES accepted to install photovoltaic panels may hold shares in the SAS SAES." (Statuts de la SAS SAES, 2008, article 8)[cxlii]

Furthermore, shares can be sold only with the agreement of the administrative council, which is the way to keep the venture territorial and "family-owned":

> "Company shares may not be sold, including among shareholders, until preliminary approval is given by the administrative council." (Statuts de la SAS SAES, 2008, article 11)[cxliii]

In this way, the firm, the farmers and the photovoltaic installations are bound together, preserving the territoriality and mutualised character of the venture.

2.1.5. Ensuring cohesion: transparency, solidarity and competence

However, the concern for ensuring that the group stuck together throughout what could be expected to be quite a ride went beyond statute matters. The president of the SAS SAES, who already had a long experience as president of the cooperative, knew that maintaining collective binds required constant work and attention, especially in a project in which so much could be at stake. As long as it works, people are all for it, but when problems appear they can change their minds quickly. It was crucial that nobody lost their trust in the cooperative. From the start, he thus decided to base his leadership on a set of principles: competency, transparency, security and solidarity through mutualisation.

> "I really supported this approach personally, that is to say, on the one hand, rigour – technical precision and competency, checking everything carefully. Solidarity among people, but which is valid, effective only with transparency. So these three elements were key. Transparency, solidarity – mutualisation – competency and effectiveness. These were the three things we tried to put into practice." (Interview 32)[cxliv]

Competency and security went hand in hand: with a small and dedicated team piloting the project, the SAS gave priority to security when choices had to be made, and took as many guarantees against potential risks as possible. They drafted a very cautious business plan, picked the most reliable and solid offer for module installations, carefully selected the buildings where panels would be installed, and took care to complete administrative procedures in due time.

Transparency, on the other hand, was necessary to maintain solidarity – which is a crucial dimension of mutualisation. It was made easier by the commitment to mutualisation, which implied that everyone would be held at least partly accountable for the project and provided a central, constant direction and a way to pull the project back in line should it threaten to drift away.

> "But I think that, because we stuck to one direction around the strategic issue of energy and an attitude that was: we will make it only through a collective and mutualised approach, these poles allowed us to stick to our direction, to stick to our vision, and to succeed." (Interview 32)[cxlv]

Transparency was ensured through regular general meetings and discussions within the administrative council, and by systematically making all relevant information available to all. The president also chose to maintain transparency and the collective dimension at the core of the project by basing his leadership on collective decision-making and trying to reach unanimity every time (Interview 32).

But, crucially, it involved being honest about the challenges and difficulties ahead, to make sure that they would not arouise suspicion or mistrust:

> "From the start, I wanted us to be transparent. I remember the first meetings very well: we are not sure we will make it, there will be problems, but we well keep you updated. Every time. Then, we'll make decisions, because they have to be made. But it seemed very important to me, rather than saying "we take care of everything". I don't like that. Because after a while, [people think]… well, 1) they do not tell us everything, 2) they can stuff their pockets and we don't know it, 3) it's only in their interest. And you break the dynamic." (Interview 32)[cxlvi]

2.1.6. A supplier of photovoltaic systems

Preliminary studies conducted by the *Fermes de Figeac* made it possible to draft a business plan and to define specifications for the supply and installation of photovoltaic systems. Having a clear idea of these requirements, the soon-to-be-officially-created SAES launched a call for tenders for the "conception, supply, installation and exploitation of photovoltaic solar plants". It was open from July, 11th to September 15th. Eleven firms were contacted directly, among which Tenesol; Laurent Causse had met their commercial director for south-western France during the meeting in Toulouse in February 2008, when the mutualised project was still just an idea. The *Fermes de Figeac* had a rather well-defined idea of what it sought, as indicated by a slide presented during the founding general meeting, which listed the key specifications as follows:

> "- target a production cost per Wc as low as possible (kit…) and reliability of the equipment in the long run;
> - system adapted to livestock buildings;
> - options for dismounting former roof covers and installing under-covers"[cxlvii]

The call represented a big amount of work and money. It was therefore rather successful. The administrative council auditioned several firms. Some of them were big and well-established in the field, some were brand-new players with little experience, and there was even a Chinese firm. They provided a sample of the diversity of firms that thrived during the short-lived French photovoltaic bubble. Members of the administrative council were quick to identify some as unreliable opportunists, as was made clear in several interviews.

> "We've seen everything. We've seen guys that… pfff!" (Interview 28)[cxlviii]
> "We quickly felt – even I, and I'm not in the field at all – I felt they were here for a gamble and…" (Interview 26)[cxlix]

They gave priority to security in their choice and favoured the offer from Tenesol, a firm specialised in solar electricity created in the 1970s and then owned by EDF and Total, which many interviewees stressed as a reassuring sign. A smaller, younger local firm was also considered, but since its social capital did not exceed a few thousands euros, it was deemed too frail to carry out a project of this scope (and rightly so, as it turned out). Even though Tenesol had never taken part in such a large project, it was backed by two major energy firms and was thus relatively immune to delays in payments or other kinds of unexpected events.

The SAS-SAES settled on a decision during the second meeting of the administrative council on 26 October 2008. A meeting in Lacapelle-Marival with the heads of Tenesol had been scheduled for the next day; to Tenesol's amazement, it turned out to be for the contract signature. At this point, first contacts were also made with local bankers, so as to present the project, assess the possibilities to obtain funds for it and start discussing conceivable options.

It only took a few months for the idea to be translated into a collective of farmers and roofs that was soon legally organised as a mutualised business and whose potential both static (in terms of solar resource and roof surface available) and dynamic (as a business plan) had been assessed and qualified. Having been thus delimited and characterised, the SAS SAES was able to interest partners and enter into negotiation with them. However, these were only first steps in adjusting the farmers' world to that of photovoltaics: several other translations and mediations would be necessary along the course of the project.

2.2. From farming roofs to photovoltaic plants

In the fall of 2008, the SAS SAES was structured as a group, had a rather clear idea of where it wanted to get to and within which timeframe, and had identified and approached key partners – namely, Tenesol and the bank Unifergie. All were embarking on an adventure, in the sense that none had ever taken part in a similar project. FIT-supported photovoltaics were a novelty, and so far its suitability and profitability for agricultural investment had been rather accidental. Very few projects had attempted to transform this fleeting opportunity into a collective device for territorial development. However robust their business plan, the SAS SAES were new to the world of electricity generation and were conscious that they were venturing into the unknown. Photovoltaic and mutualised electricity generation projects were new objects for traditional actors of the energy and financial sectors, which were not fully geared up for it yet. There was no certainty that photovoltaic policy, conceived for individual projects, could be successfully converted by a group of farmers into a source of mutualised, territorial revenue – even though it sure looked possible. Success was definitely not guaranteed.

At any rate, the project implied a series of trials, transformations and adjustments to transform a rural territory into a player in the electricity sector, on the one hand, and to transform photovoltaics and feed-in tariffs into a collectively exploited local resource. There were two dimensions to this adventure. First, the shareholders of the SAS SAES and the *Fermes de Figeac* had to become electricity producers, and do so relying on an emerging technology. Second, their collective project had to go through procedures that had been designed with individual business models in mind.

2.2.1. Creating a collective but efficient agency

The SAS SAES and the *Fermes de Figeac* set to these tasks relying on I principles described above: solidarity and transparency were put forward to enable a small and specialised team to take on administrative and technical tasks as well as the day-to-day contacts with partners. General meetings were held regularly and the administrative council was called on anytime "big" decisions had to be made. Most of the work was carried out by Laurent Causse and his team, with support from the president of the cooperative who was strongly involved in negotiations.

> "We trusted Laurent for everything, actually. For the most part. We made the important decisions, decided of the overall directions, and he took care of the main part of the work: summoning panels suppliers, and coordinating with ERDF because there was work to be done." (Interview 28)[cl]

By concentrating tasks within a few hands, the SAS SAES constituted a form of agency that was individual enough to navigate all the procedures and negotiations that a photovoltaic project implied, while remaining backed by the strength and experience of a large group (strength because it weighed more, and experience because dealing with over a hundred installations meant building up expertise). This small team's role was to take the project forward by putting together all the people, things and skills that were required for it to function: shareholders and their roofs, panel suppliers, contracts, administrative authorisation, grid connection, PV modules and their installers, funds, guarantees… As Laurent Causse put it:

> "You don't set up such a project like that. There is the financial aspect, the technical aspect, the legal aspect. We were here to unite all these people. Every time we needed a specific skill, we went looking for it." (Interview 20).[cli]

I cannot claim to describe exhaustively all the trials that the project had to go through along its course and all the choices that had to be made; for instance, I will not go into detail about fiscal issues, which were considered in depth. To give an account of the trajectory of the project, I will particularly focus on roofs. Indeed, they constitute key interfaces in many respects: they are the interface between sunlight and the electric grid, between agriculture and electricity production, and between the SAS SAES as a group of farmers and the SAS SAES as an individual economic actor. As such, they provide a lens through which to analyse the reconfigurations at play in the project. The core activity of the SAS SAES can be described as the transformation of the roofs of scattered farm buildings into a single photovoltaic park.

I distinguish between four categories of translations that these roofs had to go through: first, their selection and qualification as potential supports for photovoltaic modules; second, the redefinition of the properties attached to them in order to incorporate them into the SAS SAES business model and the following operations that were necessary to change their status from "rooftops" to "photovoltaic plants"; third, their concrete transformation into photovoltaic plants, i.e. the installation of photovoltaic systems and their connection to the grid; and, last, their role in the operation of a mutualised solar park.

2.2.2. The selection of rooftops

Early on, it was clear that not all roofs were suitable to be turned into photovoltaic plants. Several filters intervened in this selection.

The first was a preliminary internal pre-selection. As mentioned above, the "*Déclaration d'intention*" form specified preliminary criteria related to the ability of roofs to capture sunshine: orientation towards the south, sufficient inclination, no shadows. This initial filter limited the number of shareholders. Additional constraints emerged along the way and led to the exclusion of some buildings and the reduction of the group.

> "We, farmers, said on which buildings we thought we'd install panels. Then, there was a study by the Sicaseli, and […] they took all the new buildings that were made of modern materials." (Interview 29)[clii]

Tenesol, once selected as the supplier and installer of photovoltaic systems, carried out their own technical studies: between December 2008 and January 2009, they studied pre-selected roofs, taking precise measures of their areas and estimating their photovoltaic potential and the capacity of their frame to support the weight of photovoltaic modules (Tenesol, Dossier de presse, 2010, p. 3). The results of this detailed technical study were discussed by the administrative council in February 2009, and they decided to exclude some buildings that did not meet technical requirements (Agenda of the 3rd Administrative Council meeting of the SAS SAES, 2009: "ingénierie détaillée de Ténésol: complements d'études pour les bâtiments écartés, résultats; decisions quant à la prise en charge des renforcements de charpente").

> "There had been more requests, but a few roofs were excluded because they were ill exposed. I had asked for two more, well exposed roofs, but the frame was not strong enough to support the weight of photovoltaic [modules]." (Interview 31)[cliii]

According to the president of the cooperative, this selection did not threaten the cohesion of the group because it was done in a transparent and open manner and was meant to secure the project as much as possible.

> "We excluded people, because the building frame was a bit weak, we did not get technical approval, so… But we were able to be arbitrary and rigorous because there was transparency. That was the principle." (Interview 32)[cliv]

Additional filters intervened later on. The installation of a photovoltaic system requires a construction permit. These had to be requested either from relevant municipalities or from the DDT (*Direction Départementale du Territoire*), depending on the size of planned installations. A few buildings did not obtain the permits, mostly because they were old-style stone buildings with tiled roofs.

Some left the project for financial reasons, because they were afraid of the sum involved, or, later on, because they had not been able to obtain loans from bankers and could therefore not contribute the 20% that they had to. Some buildings were given up because redefining the property rights attached to them so as to make them compatible with the SAS SAES business model was too complex.

> "Some people had trouble because there were buildings in joint ownership, and it was a cause for panic to arrange all this. As a result other buildings were dropped." (Interview 29)[clv]

Other buildings were dropped for reasons related to grid connection costs: either because they were too far from a "*poste source*" or because the extension of the grid necessary to connect them would have required complicated work; they would have made the project too expensive and threatened its financial viability.

> "Then, there may have been a few exclusions because of the distance between EDF posts and roofs. […] And then, of course the financial aspect eliminated a few – very few, I think." (Interview 31)[clvi]

In fact, the composition of the prospective park had to be adjusted at virtually every step of the project. Compromises had to be made about specific buildings and situations in order to allow the group to pass through each trial, so that the SAS SAES was only established in its definite form quite late in the project: the last increase in social capital, which established the final composition of the group and of the park, was carried out in December 2010.

2.2.3. Paper trials and the requalification of rooftops

2.2.3.1. Redefining the ownership and properties of selected rooftops

Incorporating roofs into the SAS SAES collective venture involved a series of legal transformations. The buildings involved would remain private property, and still belong to the farmers, families or farming collectives that used them, but the photovoltaic systems installed on them would be owned, installed and operated by the SAS SAES for the duration of the purchase agreement (i.e. 20 years).

To enable the temporary mutualisation of rooftops, the SAS SAES would rent them. This implied the addition of a layer to the – sometimes already complex – property structure of farm buildings. As the legal counsellor of the project explains, "It was quite complicated, because often, the owner is a physical person, the building supporting the photovoltaic plant is constructed by the farmer individually or by the company for which he is a farmer, and there is a third user of the roof, the SAES. So in the end you have three owners at three distinct levels, like in a three-floor building." (Interview 24)[clvii]

Two operations were required for this legal transformation: a volumetric division of buildings into two distinct cadastral parcels, and the preparation and signature of leases. The first operation made it possible to rent the roof separately from the rest, and was therefore necessary to put the mutualised, turnkey solution designed by the SAS in practice: otherwise, the panels could not have been operated by a single entity.

"We had surveyors coming, they measured the roofs, and [the SAS SAES] rents the part of the roof on which there are photovoltaic panels. It has to be like this. That way, they receive the money from EDF, they can take care of bills… That frees us from a lot of things, because we shareholders have nothing to do, actually." (Interview 28)[clviii]

"The GAEC can rent the inside of the building, and the SAES rents the roof. The volume has been divided, if you like. So the roofs remain private." (Interview 29)[clix]

"But at first, I would never have imagined that to rent a roof like that, you needed a volumetric division of the buildings. It means that for each building, 380A is the bottom and 380B is the roof. It is funny, you can even see it on the cadastral plan, because cadastral plans have been updated. You can see which buildings have been divided in volume. It is quite funny." (Interview 30)[clx]

The second operation defined the conditions under which the SAS SAES could rent and use the roofs. It was quite complex both in the design (choice of the type of lease, redaction drafting of lease contracts, definition of a rent) and the implementation.

The design of leases involved several meetings with the legal counselling firm that assisted the SAS SAES. Two types of issues were addressed. On the one hand, issues related to general design had to be settled. The plan was to use emphyteutic leases, i.e. long leases that enable the lessee to improve the property with construction, the benefits of which go back to the owner at the end of the lease. Such contracts meant that building owners would keep the photovoltaic module after the project. In this context, determining the level of the rent paid to the farmers by the SAS SAES was quite a complicated matter, which involved several meetings and discussions with lawyers and bankers. As Laurent Causse explained, the matter was to determine whether "the price of the rent could call into question the nature of the contract: could the emphyteutic lease agreement not be called into question someday and be requalified as construction lease?" (Interview 20).[clxi]

Once these general issues were resolved, individual leases had to be written and signed; as there were over a hundred of those, this took a while. Each building had to be studied in detail. In some cases, property rights had to be arranged within families to make it possible to sign the leases. In others, further changes in the organisation of farms had to be made to avoid too heavy a fiscal burden. Each case had to be considered individually, providing work for notaries and legal counsellors.

"There was a provision, too, specifying that the person taking part in the project had to own the building and the plot. That was what we wanted. Notaries in the area were happy, because family arrangements had to be negotiated. It unblocked several situations. People made family arrangements…" (Interview 28)[clxii]

"[Leases] were fastidious because we had to find the origin of property, the acts… It was complicated to know who was the real owner of the building, it's always the same. And

> when we told farmers, the building belongs to your wife because she owns the land, in a rather macho world, it did not go smoothly… So their wife was going to sign the lease and receive the rent, so all at once they concluded, if she leaves, I won't get the rent, wow." (Interview 25)[clxiii]
>
> "I hosted a few meetings to explain to farmers the fiscal and social consequences of these additional income from photovoltaics. Because this is complex indeed. It depends on everyone's situation. That is to say, this photovoltaic income, the company's dividend, will not be taxed in the same way if the farmer is self-employed, if he is part of a company, if he is on flat-rate agricultural income [*bénéfice agricole forfaitaire*] or on real agricultural income [*bénéfice agricole réél*] […]." (Interview 25)[clxiv]

Given the number of cases to be sorted, the leases were signed in several sessions spread out from March 31, 2010 to January 28th, 2011. The completion of this relatively tedious legal task was necessary for the incorporation of soon-to-be solar roof into the SAS SAES organisation, but it was not enough to turn these roofs into photovoltaic plants.

2.2.3.1. Framing rooftops as electricity generation sites

In the summer of 2009, the SAS SAES had declared the buildings that would be part of the photovoltaic park as "warehouses with no legal ties with others" and more specifically as "site[s] for the generation of electricity from the sun's radiative energy (photovoltaics)" ("*site[s] [de] production [d']électricité à partir [de l']énergie radiative du soleil (photovoltaïque)*") (SAS SAES, Déclaration de modification personne morale, 2009). The signature of leases gave legal consistence to this relationship between the company and the buildings. The materialisation of this relationship implied further transformations of the roofs, since those had to be actually turned into photovoltaic plants. This operation cannot be reduced to the mere installation of photovoltaic modules on the roofs and their connection to the grid: it also involves an administrative reconfiguration of the buildings and their roofs, as well as a reconsideration of their position within the electric grid.

What could be called the procedural part of these transformations, i.e. all the paperwork required to obtain the authorisation to install a photovoltaic system and connect it to the grid, to secure access to feed-in tariffs, and to determine the conditions and price of grid connection, may well be the most crucial. Indeed, it conditions the construction, the profitability and the putting into service of the photovoltaic park. That is why this was the one set of tasks for which the SAS SAES did not rely on other parties. In Laurent Causse's words, this was far too important:

> "[Tenesol] took care of everything. They installed, they delivered the plant turnkey. But we took care of all the administrative work. They did not do the paperwork; we kept that. Because in my opinion, it was too important. You can't entrust someone with it and risk losing everything. To me, it was clear that we had to keep it. And looking back, we were right. If you remain dependent on someone else like this… you can fight all you want on the phone, if the guy doesn't do his job, he doesn't do his job." (Interview 20)[clxv]

The administrative road to the installation of a photovoltaic system is long and winding, and it was even more so in 2009. It involves three steps:
authorisation to install the system;
authorisation to connect it to the electricity grid;

authorisation to sell the electricity generated to EDF and to benefit from the feed-in tariff.

Each authorisation had to be obtained individually for each planned installation and through distinct procedures. The SAS SAES solar park comprises 109 photovoltaic plants (and initially included more): the staff of the Sicaseli had to complete well over a hundred files for each step. Of course, it was easier than if every member of the company had done it individually, but one can imagine the level of organisation it required.

> "So, imagine, in Lacapelle, over there in the office; Sylvain, Laurent, a secretary; 115 individual files. […] We send the file to EDF, they send it back with a stamp, we approve, it comes back. It goes back. When something is missing, back to the start. Well, imagine, to obtain the agreements, the validation, how many times the files had to go back and forth." (Interview 30)[clxvi]

To add to the challenge, the SAS SAES mutualisation model was articulated around homogeneous feed-in tariffs. They had designed the project on the premise that all installations taking part in the project would do so under similar terms: grid connection costs should not differ too much, and all installations should benefit from the same feed-in rate. Not managing to secure the same FIT for every installation would have involved a re-articulation of the business model, thereby threatening the profitability of the project. As the SAES suspected that the idyllic FIT situation would not last forever (and rightly so), the process took place in quite a rush.

Prior to the rest, the SAES had to obtain construction permits for all the buildings, so as to ensure that photovoltaic systems could be installed. This involved sending files to either the relevant municipalities if they had a division for urbanism, or to the DDT. Once this preliminary step was completed, the SAES was able to work on the two others: grid connection requests and purchase agreements.

2.2.3.1.1. Dealing with ERDF: grid connection procedures

Procedures related to grid connection are managed by ERDF, the utility in charge of the distribution grid. Requirements depend on the capacity of the electric installations to be connected. In that regard, the type of mutualisation chosen by the SAES did not simplify things. Indeed, though they had chosen to have homogeneous feed-in tariffs, they allowed heterogeneous types of buildings and installations in the project. At the time, as long as the installation was building-integrated, its size and capacity did not alter the applicable FIT level. It did, however, influence administrative procedures, especially for grid connection.

For installations over 36 kVA, technical and financial studies are conducted to establish a grid connection proposal (called *"Proposition Technique et Financière"*) within three months after the reception of the grid connection request; if this proposal is accepted, further and more detailed studies have to be carried out to determine precisely how connection will proceed and to draft the three necessary contracts: a connection contract (*convention de raccordement*), an exploitation contract (*convention d'exploitation*) and a grid-access contract (*contrat d'accès au réseau*).

The procedure for installations under 36 kVA is simpler. A single document details the conditions for connection, exploitation and access to the grid: the CRAE (*Contrat de raccordement, d'accès au réseau et d'exploitation*). Once accepted and signed by the producer, and once it has been established that the electricity to be generated has a purchaser (i.e., in the case of photovoltaics, once the purchase agreement has been signed with EDF), the installation can be effectively connected to the grid and put into service.

Box 3: Grid connection procedures as explained by an interviewee from ERDF Sud-Ouest

"Files were, as we say, 'qualified', declared acceptable. Then, we make studies, we establish what we call a 'technical and financial proposal'. So, the engineering office established the proposals, it was my responsibility at the time to approve them. Then we conducted more detailed studies once the PTF, this technical and financial proposal, was accepted. We conduct a more detailed study, saying: we're going to set a cable in this place, this will cost this much. Then, we establish a contractual document or the site lifetime, that is a grid connection contract that says: connection to the grid of Mr. Smith's site requires that many meters of cables of such section, the limit of the property is there, metering will be of this kind, etc… So that is part of the documents that give access to the grid. On the one hand, you have the *convention de raccordement*; then, you have the CARD*, contrat d'accès au réseau de distribution pour injection*. This is to allow the producer to access the grid to deliver his energy. The *convention d'exploitation* defines the rules in particular related to safety, because an electricity generation installation can send electricity back to the grid, so if there is an accident we need to know where it comes from. All that is part of the *dispositifs contractuels d'accès au réseau*, so it involves payments, signatures, etc… And then, we put into service when we know that the producer has what we call a *responsible d'équilibre*, that is to say someone to purchase his energy." (Interview 25)[clxvii]

At best, the whole process takes several months, but it can sometimes last over a year. Delays could be especially long in 2010, given the amount of requests for photovoltaic installations that ERDF had to process without having had time to adapt to this new type of generation plants. However, given the number of requests the SAS SAES brought to the table, they managed to establish a working relationship with the regional ERDF division. Laurent Causse remarks that it simplified matters:

> "And it's the same for ERDF. They knew us. So we were able to talk. At one point, there was something completely aberrant, we went to see them, we talked, and we settled the matter." (Interview 20)[clxviii]

2.2.3.1.2. Dealing with EDF-AOA: Purchase agreements

Things were more complicated with EDF-AOA, the branch of EDF in charge of delivering and implementing purchase agreements. At the time, any future photovoltaic installation had to obtain a governmental authorisation to be able to qualify for FIT, the *Certificat ouvrant droit à l'obligation d'achat* (CODOA).[141]

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[141] This obligation was suppressed in March 2009 for photovoltaic installations under 250 kWc and, later on, for all photovoltaic installations under 12 MW.

Before facing the machinery of EDF, the SAS SAES had to contact the representatives of the State in charge of delivering these certificates, which was the DREAL Midi-Pyrénées. At this level, the size of the project allowed the SAS SAES to benefit from a special procedure and direct contacts with administrative officials.

> "We met several times to deliver the certificates, and in that case, given the number of installations, we had better meet ahead to optimise the delays for processing the aforementioned certificates, because they did not want to have one certificate after the other. They wanted to have all the certificates before starting the project. Well. So we arranged a special operation for the CODOA." (Interview 23)[clxix]

With EDF-AOA, no such contacts were possible. This branch of EDF, based in Lyon, operates on a national level. In the late 2000s, it was undergoing an unprecedented growth driven by the exceptional increase in purchase agreement requests that the high feed-in tariffs for PV-generated electricity had triggered. Securing the feed-in tariffs at the same level and under the same conditions for all the photovoltaic installations in the project was critical for success, but the SAS SAES had to wait for each individual request to be processed without ever managing to find a dedicated contact point.

> "And with EDF, no way to have an interlocutor. We asked for one – given the size of the project, from the start, we asked for a phone number, someone, if there is a problem, let us know. Impossible. It was not possible. So imagine how many shuttles back and forth were needed… Well, I did not see all that. But every time we had administrative council meetings, they would explain: of 115 files, 40 are at this stage in the process, 30 are at that stage, 10 at that stage…" (Interview 30).[clxx]

Interactions with EDF-AOA were probably those were the tension between existing procedures designed for individual projects and the collective nature of the SAS SAES project was strongest. All the installations eventually managed to obtain the same feed-in tariff. As these are determined according to the date of the reception of the grid connection request by ERDF, FITs were secured at their peak, in June 2009. However, by December 2010, all purchase agreements had not been signed yet, and the installations (which were all ready by September 2010) could therefore not be put into operation simultaneously.

2.2.4. The material transformation of rooftops into power plants

The completion of paperwork and the resulting registration of farm buildings as generating units in the electricity grid (ERDF) liable to receive a set tariff (EDF-AOA) enacted their full transformation by enabling the photovoltaic plants to be put into service and took place in parallel with significant physical modifications. For this part, the SAS SAES relied almost entirely on Tenesol.

2.2.4.1. Installing photovoltaic systems

Installation work spread over a full year, from September 2009 to September 2010. It started a couple of months after the banks gave their agreement of principle for financing. At this point, FIT levels had been secured and the overall financial structure of the project was established, but legal and administrative procedures were still far from completion. Many of the transformations of the roofs that I describe in this chapter thus occurred simultaneously.

Despite several decades of experience in the photovoltaic sector, Tenesol had never led a project of such scope. Before the FIT era, it was specialised in photovoltaic module supply for isolated systems, mostly in French overseas territories. The modularity of photovoltaic panels combined with the flexibility of feed-in tariffs created a demand for all-inclusive offers comprising module supply and installation, which was a challenge for Tenesol. For the firm to adapt to this new business framing of photovoltaics it had to combine two very different professions: module supply and photovoltaic system installation. The tension between those two activities was manifest during the realisation of the SAS SAES project. The Tenesol management team came from the automobile industry, where assembly processes are calibrated and predictable (Interview 33). The SAS SAES project, on the other hand, involved the supervision of over a hundred building sites spread out over a large rural area, and all of which had to be completed within a relatively short time frame. In an operation of such scale, unexpected incidents were unavoidable. The on-site construction management team and the senior management team, based in Lyon, had wholly different perceptions, and the project led to a sort of professional "cultural shock".

> "They were really not on the same wavelength. Simply because one was on site and had to deal with day-to-day problems, and did not understand that it all had to fit in an Excel spreadsheet for matters related to accounts, to financing… And the other one with his Excel spreadsheet did not get that… well, the firm did not come, so the panels are still down there on the field." (Interview 33)[clxxi]

As Laurent Causse notes, Tenesol was not fully ready for that and the project clearly forced them to evolve:

> "We chose a supplier called Tenesol, which was in fact not ready at all, and which we forced to evolve. Because we did not like their first offer at all. They were not adapted to our system at all." (Interview 20)[clxxii]

Because it was an innovative and ambitious project in a sector that was emerging and evolving quickly, it created a close relationship between the Sicaseli and some employees at Tenesol who pushed for the project within the firm. This form of "complicity" was key in performing the transformation of the individual model that prevailed in photovoltaic systems into a more modular version that was fit for mutualisation. The timing was well-suited for that, since the photovoltaic market was in full expansion.

> "I fought [within Tenesol] rather than with [Laurent Causse], because [at Tenesol] they did not want to do the project. Tenesol is a nice firm, but not a very brave one, I would say. Not very risk-prone. […] And I did not want to let go, because my objective was to make [the South-West branch] bigger. […] and I thought: I need to get a big project so that it can go fast, otherwise…" (Interview 33)[clxxiii]
>
> "We managed to... not create complicity, but to build the project together, while being customer/supplier and confronting each other, because, necessarily there are clashes." (Interview 33)[clxxiv]

The project was indeed complicated to orchestrate. It implied uncovering roofs, in several cases, cleaning up asbestos and/or reinforcing building frames, and them setting up the "Tenesol system". A press release from Tenesol describes the operation as "twelve months of construction work, including six months at full load, with a mean of 25 sites simultaneously". Such a workload required the involvement of many subcontractors, which Tenesol did its best to recruit locally.

"Imagine, to install 55,000 m^2—uncover 55,000 m^2 of rooftops, cover them with 55,000 m^2 of photovoltaic panels! The staff at Tenesol was not able to—they did not have the staff to do it. Nobody had enough staff to do it. We contacted all the carpenters in the area." (Interview 30)[clxxv]

2.2.542. Putting installations into service

Once a photovoltaic system is installed, two further operations are necessary to the conversion of sunlight into electricity that can be sold at the feed-in rate (cf. supra part 2.2.4). One of them is paperwork: a contract needs to be signed between EDF-AOA and the prospective electricity producer to register the new production plant and establishe the conditions of the transaction. The second, grid connection, involves both paperwork and physical connection. Given the number of installations included in the SAS SAES park, these three operations (installation, connection, purchase agreement delivery) spread over a year and a half. The first systems were installed in September 2009 and connected to the grid in December of that same year; the last one was put in operation in March 2011.

In 2009 and 2010, installations thus progressed individually, each at its own pace. Production started as soon as the first system was connected, but the park itself did not exist as a whole until all were connected to the grid and to the electricity market. As a result, some members of the group found this a rather stressful period: the production of many installations could not yet be turned into cash, and valuable sunshine was as good as lost. The owner of one of the biggest roofs and one of the very last connected, is one of them:

"And the connections… Because we forgot to tell you, our system was ready to be connected in early July 2010. Jacques Calmejane [a neighbour also in the project] was connected in August, by the end of August. We were connected in October for the small one. And the large one was not connected until January-February of the following year! So you realise the amount of production that was missed! You are ready to produce, and you cannot send it to the grid!" (Interview 26)[clxxvi]

These delays owed partly to the fact that both EDF and ERDF were overwhelmed by requests related to photovoltaics, and partly to the geography of the region.

"While the administrative part was long and complex, on the field, ERDF interventions up to the putting into operation were made difficult by the complexity of the cases and by the influx of photovoltaic grid-connection requests." (Tenesol & Sicaseli, 2010)[clxxvii]

Ségala-Limargues is a hilly and loosely populated region with little need for new electricity generation capacity. The work necessary to connect nearly 200 photovoltaic systems to the grid was both complex and of low priority on the grid operator's agenda. Ironically, the weather proved an unlikely ally for the SAS SAES. A drought in the summer of 2010 diminished the capacity of dams, creating a need for electricity generation capacity and therefore inciting ERDF to speed up the connection of these new – and suddenly useful – photovoltaic plants.

"For us, [...] grid connection took place a good six months after the end of installation work. Easily. It lagged. [...] They did a lot in July-August, because we were lucky – well, lucky and unlucky – with a drought in 2010 [...]. So, they had the hydroelectric dams there. And in July-August, they plugged all the buildings that were ready, within a fortnight they plugged everything. To compensate. [...] They emptied the dams during the night, and used photovoltaic electricity during the day. That's what helped us." (Interview 29)[clxxviii]

2.2.5. Elaborating a collective solar intelligence

As the putting into service of the individual photovoltaic plants spread over such a long time, it is difficult to determine exactly where the realisation phase ended and the operation and maintenance phase began. Electricity generation and sale started as soon as the first installations were put into service, that is, long before the project was actually completed. Mutualisation made this possible without running the risk of disintegrating the group, since all shareholders received the same revenue per kWc installed no matter what their own installation actually produced.

However, the SAS SAES as a group of farmers *and* as a photovoltaic production firm was not stabilised until the last roof was connected to the grid and the last purchase agreement was signed. Only then could the photovoltaic park be considered and operated as a single, stable entity.

2.2.5.1. Mutualising maintenance

The operation and maintenance of this entity are based on an organisation specific to the SAS SAES. It is to a large extent made possible by the constitutive choice of mutualisation. Operation and maintenance function according to the same principles that prevailed at the project's initiation and realisation: tasks are delegated to a small specialised team, but information is provided regularly and every shareholder also has a share of responsibility. Three people based in the *Fermes de Figeac* offices are in charge of monitoring the park: Laurent Causse, one engineer and one technician in charge of field operations.

This team plays a crucial role in organising the scattered photovoltaic installations as a single mutualised park. In particular, they are in charge of monitoring the production and functioning of all the installations. The inverters included in photovoltaic systems are connected to the Internet and send both live information (with updates every 30 seconds) and daily reports on the functioning of each installation. This information is centralised on a computer in Lacapelle-Marival, where software designed for that purpose makes it possible to monitor the production of the park and compare sunlight and electricity production among the individual photovoltaic plants. These devices enable the staff based in Lacapelle to view the park as a whole and to map the local "sunshine situation" at a given time. The geography of the park – scattered over a rather large area but with bunches of installations located close enough to each other to be exposed to the same conditions – makes it possible to map sunshine and rapidly notice discrepancies in production, thereby pinpointing malfunctions.

> "Today, we have developed our own device, which is unique by the way. Since we're in a rather clustered area, we can compare installations to each other; and as soon as an installation lags behind, we think there might be a problem. When you see an isolated installation, if it produces less, you cannot tell if its because a cloud passed over or if… Whereas here, we can see it. Usually it is because it gets dirtier than the others. But sometimes we have small problems. Once, there was no alarm on an installation, but it

produced less; and as we can compare with the other installations nearby, we can have rather reliable elements [of comparison].” (Interview 20)[clxxix]

Those in charge of monitoring and maintenance have visited all the installations and are in contact with all the shareholders of the SAS SAES. A communication system has been put in place, so that farmers receive a text message or a phone call signalling problems and asking them to check their installation whenever data and statistics suggest there is something wrong with their photovoltaic system.

> “We have organised a system based on text messages, etc. Because now, all the roofs are connected to Lacapelle-Marival. Every morning, there is a guy [..] who checks if it all works well.” (Interview 28)[clxxx]

This is not only an efficient way to monitor the functioning of the park, it also maintains the involvement of farmers in the operation of the photovoltaic systems, as a quote from Christian Vermeil suggests.

> “[…] we are involved a little. We are farmers, it is in our interest for it to work […]. Here, you can see [the panels] easily, on the building down below. When we get there, you have the inverters outside, when we pass by we have a look to see if they’re flashing. Il one is flashing, we call.” (Interview 29)[clxxxi]

2.2.5.2. The integration of photovoltaics into a routine and a landscape

Most of them thus keep a more or less regular watch on their installation and alert the *Fermes de Figeac* if they notice anything wrong, even though distant monitoring is far more efficient. Indeed, after a while, the photovoltaic systems have become part of their routine. They do not require any form of work on the farmer’s sides (apart from occasional check-ups), they do not seem to disturb animals much[142], and the monitoring and maintenance system ensures that incidents are resolved quickly. As a result, farmers do not really need to pay much attention to their photovoltaic systems. Even those who enthusiastically took careful notes of their daily production in the first months gradually lost interest and now simply check that all is right with a glance when they pass by the installation.

> “[…] At first, everyone was happy, some even had a small notebook and every day they noted their daily production. And I talked about it with a friend, he told me: ‘I stopped doing it, because I’m tired of going to see if it works or not everyday.’ […] I suspected this much, because over 20 years that’s a long time. Checking every morning… We check once in a while. […] I used to write it down once a fortnight, but I stopped. No, we check that it’s working and then…” (Interview 28)[clxxxii]

Photovoltaic modules have become fully integrated within the rural fabric of the territory and the daily life of farmers. They come back to their attention when there is a punctual problem, when general meetings are held or when they receive their rents and dividends but overall, they are now unproblematic, stabilised and pacified.

Their integration into the landscape goes further in that the photovoltaic park has made it possible to develop a new form of knowledge about the territory through the inclusion of variations in sunlight among its characteristics, as Laurent Causse pointed out:

[142] This raised concerns at first, cf. Roussies.

> "It is funny, because we're mainly on the eastern part of the *département*, and it's true that we can now see a rather clear difference between zones. In fact, as it turns out, the northern zone produces the most, because it is at altitude. Zones at altitude are sunnier, they are less foggy in the winter, they are cooler as well, so on the whole it yields better." (Interview 20)[clxxxiii]

2.3. With the Sun and the State: demonstrating the viability and profitability of the project

The mutualised maintenance system is one of the devices set up by the SAS SAES to maximise the profitability of their venture. It is indeed much more efficient for them to take on this responsibility than to outsource it. This owes to their geographical proximity with the installations and their resulting good knowledge of the park, since these two factors enable them to react quickly to any incident or problem.

But another reason for this increased profitability and efficiency is directly linked to mutualisation. Since the profits of shareholders depend on the overall production of the park, and not on the individual production of "their own" installation, their best interest lies in maximising the production of the park as a whole. The higher above previsions they stand, the more profit they get: each lost second of sunshine is a loss of money. Whereas an outsider firm would have no incentive to maintain electricity production above the levels anticipated in the contract, in is in the best interest of the SAS SAES to do so. The 3 or 4 percent that their reactivity earns them actually make the difference, and are what their benefits depend on, as they explain.

> "We can see that the difference comes from these additional 3 to 4% that very often make the profit. And these additional 3 to 4%, you need to go grab them. And you do that through proximity, competence and reactivity. And that's one of the strengths of the collective: we have the right perimeter to offer such maintenance. Objectively, that is decisive." (Interview 32)[clxxxiv]
>
> "In May, during the longest days when it produces full blast, you cannot afford to mess up. Even if you run after it you cannot catch up. You have to be very reactive." (Interview 26)[clxxxv]

The organisation of maintenance illustrates how the *Fermes de Figeac* organised mutualisation as a way to ensure the viability and increase the profitability of the project. Indeed, the project is first and foremost an investment into the development of a local resource made extremely attractive by the opportunity constituted by FITs. It is about renewable energy production but, more importantly, it is about making the most of an exceptionally interesting economic opportunity.

2.3.1. Framing a golden opportunity

As such, the full realisation of the project involved a critical financial dimension: the photovoltaic park can only exist as long as it is financially viable and preferably financially profitable. Financial viability was the crucial condition for it to attract interest from farmers as well as from photovoltaic modules suppliers and to obtain loans. If this viability could not be demonstrated in a manner convincing enough to enrol partners and allies, the project would have remained a virtual park.

The *Fermes de Figeac* and the SAS SAES thus had to assess and articulate potential risks and profits so as to demonstrate the relevance, viability and interest of their idea. Determining risk levels was even more important because the photovoltaic market was new and emergent.

> "Photovoltaics were a new technology, we don't have much experience with it. Novelty necessarily implies unknown, so a risk that is not mastered, and all the challenge was to understand this mechanism, to understand the risk to see if there was a risk if it was consistent… well, to assess which amount of risk we were taking." (Interview 20)[clxxxvi]

Nobody was used to this mode of electricity production and this type of investment yet, which made it necessary to determine clearly how it could be made profitable. FIT-supported photovoltaic projects were backed by the Sun and the State: two virtually infallible guarantors, but rather unfamiliar associates. Photovoltaics presented an interesting opportunity, but the terms of its profitability were yet to be established clearly. An interviewee nicely described the bemusement that ensued:

> "If you'd like, it was a specific case, because on the one hand, profitability was there. There was no doubt about it. We had no previous experience, but we had some in Germany for instance. But bankers – and farmers themselves – were not used to production that did not involve any labour, and that depended on an external element, the sun, that is always there. So they tried to bury their head into the sand, I think, for that reason." (Interview 24)[clxxxvii]

2.3.2. The SAS SAES business plan

The original motivation of the project was to convert the solar resource available into a new source of revenue for the territory and the farmers. It follows that one of the first conditions for its realisation was to translate the idea into an assessment of investments and profits. In other words, one of the first trials that the idea had to go through was the elaboration of a business plan that translated it into financial terms.

Four elements are decisive in the SAS SAES business plan: the level of the feed-in tariff, the radiative potential in the area, the expected costs of realisation, and the level of interest rates. The feed-in tariff determines the level of profitability of generating one kWc of photovoltaic electricity; once obtained, it is guaranteed for twenty years, which means that it also provides the temporal frame of the project. The radiative potential, or in other words, the average solar resource available on the territory, fixes expectations as to the amount of photovoltaic electricity that the project leaders can expect to produce over twenty years. The costs of the project could be known with a good degree of precisions once the call for tenders had been launched, that is quite early on. Last, interest rates are crucial in the equation since they establish the price of financing the project through loans.

The business plan was based on feed-in tariff rates for BIPV as of 2009 (the potential evolution of FITs could not be forecasted, anyway). For the other two variables, the SAS SAES considered several hypotheses, and ran simulations to build a range of more or less cautious scenarios.

> "Well, now, we had a very secure business plan. We based it on a level of energy resource at 1020 [W/m^2], which was relatively secure." (Interview 32)[clxxxviii]

On the basis of these scenarios, the SAS SAES was able to sketch the expected financial trajectory of the project. They divided it into three phases: an investment phase with no net benefits until 2012, a 12-year long intermediary phase in which profits from electricity generation are used to pay back loan, and eventually a very high-profit phase. In sum, the mean net profit over the project lifespan is 20 €/m²/year, as Laurent Causse explains.

> "So there are three periods. First, start and installation. Then, for a dozen years, [the farmers] do not get much in net benefits, because they have to pay back loans. And then, it goes up very fast. From the years 13, 14, 15 onwards we end up with remuneration levels over 50 €/m². On average, it's 20€/m²/year. That was the plan." (Interview 20)[clxxxix]

2.3.3. The SAS SAES business model

The business plan, articulated around feed-in tariffs, was rather secure and based on cautious hypotheses. The structure of the venture, largely determined by the choice of mutualisation, was more audacious.

In mutualising, the objective was to provide access to photovoltaics to the largest number possible. It resulted in a large-scale, hence very expensive project. During the first years of the project, its total cost was anticipated to be about 41 millions euros. It turned out to be a little less, 33.7 millions euros, but it still represented a considerable sum, the likes of which neither the Sicaseli nor Tenesol had ever worked with.

2.3.3.1. Mutualisation as a business model

The project thus required important investments. The bet was to have it almost entirely funded by loans. Shareholders had to bring in 20% in capital stock, each paying for 20% of the investment on their roof; in most cases, farmers contracted loans to ensure this initial contribution. The remaining 80% were to be loaned by the SAS SAES. However risky, this business model articulated around mutualisation enabled many farmers who could not afford an individual installation to take part in the project, which was the objective.

> "I would say that regarding the financial aspect, it was important that… the project enabled people who did not have the financial means required to do it. That was the original idea. With, even if I should not tell it to bankers, 100% funded by loans." (Interview 20)[cxc]
>
> "There was a very interesting financing structure under which they had to bring 20% of the sum in self-financing – well, not necessarily in self-financing, they borrowed it themselves, but they only had to finance 20% of the investment, the remaining 80% being paid by the [SAS SAES] directly. So that enabled these sheep breeders, who are not wealthy, to diversify their revenues right away. And for some of them who did small installations, if it brings them 4000 or 5000 euros a year only, it's already a lot. So the interest of the operation lies in the collective that allows 'small farmers', so to speak, to be part of such a project." (Interview 24)[cxci]

Mutualisation also determines the allocation of revenues, and the SAS SAES chose of form of mutualisation that remunerated every installed square meter of photovoltaic panels equally. The company "pays a rent. But since we are shareholders, we own the company, and in the end, if there is any income left, the money will get back to us. So, in fact, we are going to earn the whole product of the sale of electricity, either as rent or as dividends. We pay the functioning costs of the company…" (Interview 30).[cxcii] In the SAS SAES model, all shareholders get the same profit for each installed kWc, no matter the actual production of their photovoltaic plant. This significantly reduces uncertainty as to the expected profit of shareholders.

Two conditions needed to be met for this model to function. First, all installations had to sign a purchase agreement under similar terms with EDF – that is, all had to get the same tariff rate, so that the "we have one square meter installed, we earn for one square meter" (Interview 30) principle holds. That is why the SAS SAES was under pressure to secure the feed-in tariffs for everyone, and focused on this issue at the start.

Second, the 20% in capital stock had to be provided, implying that all shareholders had to have access to loans if they needed it, and, as far as possible, under similar conditions. As mentioned above, this condition led a few of the initial shareholders to leave the project. The SAS SAES and the Sicaseli negotiated with local bankers to ensure that all members of the project would have access to the same types of loans.

2.3.3.2. Mutualisation as a guarantee

The SAS SAES designed its mutualisation model as a way to enhance project security: they chose to harmonise what they thought would provide guarantees for financial viability. Under these conditions, the understanding of the SAS SAES was thus that mutualisation constituted an additional guarantee. As far as participants in the project are concerned, this is rather straightforward: they weigh more in negotiations, and potential problems are diluted in the group (whether it is bad weather – which will hardly ever affect *all* roofs at the same time –, an incident with a photovoltaic system, or EDF payments arriving late). Mutualisation is a way to smooth out profit, as the average pooled production of a 109 photovoltaic plants scattered across an area is more stable than that of a single, isolated plant.

The mutualised structure of the SAS SAES provides further guarantees in that it distributes interests and responsibility among shareholders while delegating critical tasks to a specialised team. Since members of the SAS SAES effectively own the company, they are collectively (and individually as well) responsible for their own earnings. These earnings depend on the smooth operation of the park, hence of their individual photovoltaic installations. Mutualisation and delegation of routine and administrative tasks to the *Fermes de Figeac* made it possible to select the most suited roofs and to design a particularly efficient maintenance system.

Last, by enabling the SAS to constitute a large project and entrusting a few skilled people with negotiations, it shifted the balance of power on the SAS SAES side when dealing with partners. Not only was the photovoltaic modules supplier and installer picked for its financial solidity and reliability, it was also much more dependent on the success of the project than it would have been with a venture of a smaller scale.

> "We had this power, to [tell Tenesol]: 'ok, guys, you have this roof to install, you have a big project, it means 36 million euros for you, that's quite a lot of money…' And that put them to work. We had a hold on them." (Interview 28)[cxciii]

2.3.4. Negotiating funds

The SAS SAES and the *Fermes de Figeac* thus took care to assess risks and take guarantees. The project represented a considerable risk for the *Fermes de Figeac*: they could not afford a failure – both financially and in terms of credibility. The business plan and business model were devised so as to limit and control risks as much as possible. In the end, the project was secure, at least from the point of view of the *Fermes de Figeac*.

Though it suited the SAS SAES, this assessment and articulation of risks turned out to be insufficient to fully convince potential lenders. To obtain funds, the SAS SAES had to embark on long negotiations with bankers, who have a different culture of risks and perception of mutualisation. Position shifting and adjustments were necessary on both sides to reach a compromise over risk management.

> "And we told [the bankers] that is was like the sum of several projects, but we provide more guarantees than an individual project, since we mutualise. And by mutualising, we secure good maintenance. That too was not easy to have them understand." (Interview 20)[cxciv]

The *Fermes de Figeac* and the SAS SAES first contacted the local Crédit Agricole, which sent them to Unifergie, its subsidiary specialised in funding renewable energy projects. The man who was in charge of the project at Unifergie remembers discussions as early as October 2008:

> "So in October 2008, we begin to mention the case, saying, well, we are thinking about it. A questionnaire had been sent to Sicaseli to see how the project was technically arranged." (Interview 34)[cxcv]

Photovoltaic projects had first developed in the rural regions in the South of France, because "the rural world, you know, is a world with storage requirements, with constraining means regarding their activity, the variation of their activity, so arriving with a solution that allowed them to build a self-funded building, that was exceptional" (Interview 34).[cxcvi] As the leading bank in the agricultural community, *Crédit Agricole-Unifergie* was at the forefront of photovoltaic projects funding. When they first heard of the Sicaseli's project, they already had some experience in the field and were thus equipped to assess the specific risks related to photovoltaics.

> "[…] As the *Crédit Agricole* was ahead of our other partners, we had had the opportunity to think over processes to secure decision-making; we considered the issues a little before the others, setting up devices to assess technical risks." (Interview 34)[cxcvii]

In particular, they had already funded collective and mutualised photovoltaic projects, including that of the SA4R (Interview 34). They were thus willing to take part in the SAS SAES project, but they had never seen a collective project of this scale:

> "At this stage, we were dealing with about five times, four to five times, what we had seen before." (Interview 34)[cxcviii]

Where the SAS SAES saw mutualisation and the security it provided, the bankers saw over a hundred individual cases to assess. From their point of view, size and mutualisation were a difficulty rather than a guarantee, even though it divided risks for participants.

> "From a general perspective, what we can say about such operations is that the interest of mutualising lies in splitting risks; the inconvenient of mutualising is that there's too

> many people, and in the event of difficulties, of dysfunction, it is complicated to sort out." (Interview 34)[cxcix]

From the bankers' perspective, the size of the project was a problem for two main reasons: first, because it multiplied work, and second, because its cost was such that Unifergie was not able to take on funding by itself and had to constitute a syndicated loan.

2.3.4.1. Mutualisation as an amplification of work

One key issue regarding the amount of work required to release funds for such a project was that the bankers and the farmers had a different understanding of it. Unifergie gave its agreement of principle in July 2009. For them, it meant: "we are ready to consider the case in such and such context" (Interview 34). The SAS SAES, on the other hand, took it as their cue to launch installation work. From the perspective of the SAS SAES, the project was mature and secure enough not to require in-depth reconsideration once the agreement of principle had been given.

> "From the project developer's perspective, [obtaining the loan] is a simple step, easy too implement, because it has been thought out and carried out for a while to the extent that all issues seem to be settled. From the banker's perspective, the issue is slightly different, because he is discovering a file that he has to audit. […] And when this file arrived, it raised issues, for the banker, that were beyond what the project developer could have imagined." (Interview 34)[cc]

Even Unifergie did not fully realise what the project would imply when they gave their agreement of principle. They had never seen a project of such scope before, and since they had managed to conclude deals on similar, but smaller, projects, they probably did not foresee it might raise unexpected difficulties.

> "I believe that the back-offices of the banks were not ready to manage such levels of complexity, which went far beyond what we had imagined when we accepted this case in our internal credit committees." (Interview 34)[cci]

Indeed, finalising lending conditions implied a re-assessment of the guarantees taken by the SAS SAES. The articulation of risks proposed by the SAS SAES had to be evaluated and translated into the world of finance and banks. This turned out to represent a considerable amount of work, given the amount of individual cases to consider.

> "The second difficulty, from the banker's perspective, was the size of the project in terms of acceptability, therefore of risk appreciation. Because we were dealing with investments nearing 40 million euros at the time, with all the project developers. They explained that a lot of work had been carried out ahead to discard the farmers who did not have the capacity to carry leases, those who were not well located, those who did not have suitable roofs, etc… So we thought, putting over 30 million euros on the table, with risk levels that had been pre-validated, or qualified among project developers… Even if on paper there had been this pre-qualification, we nonetheless had doubts over risk appreciation. We thought, this has to be looked over twice." (Interview 34)[ccii]

Double-checking the SAS SAES project implied a detailed assessment of all the documents and situations of each of the 109 photovoltaic plants included in the project. An operation that is not necessarily complex for a small project thus took considerable proportions here, and generated a workload that far exceeded expectations.

> "From the banker's perspective, [mutualisation] is not a simplification, but a complication. That is to say, when we say 'we have a lease', you indeed have a legal

> document, but behind it, there are as many leases as there are buildings. They have to be controlled. We say: 'we have an insurance'; certainly. Only there are as many insurance policies as there are sites to control. It implies, from the banker's perspective, a multiplication of work that admittedly could be industrialised to an extent, as it is rather repetitive, but that is not simply copy-and-paste. Each case is specific, so we have to scan all of the documents for control, for verification. We cannot say: we have controlled some documents, and we assume they are okay for all sites." (Interview 34)[cciii]

2.3.4.2. "Mutualisation" of financial risks: syndicating a loan

Another consequence of the size and complexity of the project was that Unifergie and the regional Crédit Agricole branch were not able to take on the loan in its entirety. The scope of the project required banks to be involved at the national level. It also made it necessary to split risks among several banking establishments through a syndicated loan. Unifergie served as the leader and arranger of the syndication, which ended up including three branches of the Crédit Agricole – Auxifip at the national level and two regional branches (Crédit Agricole Nord Midi-Pyrénées and Crédit Agricole Centre France) – as well as three other banks (Crédit Coopératif, Oséo, and Banque Populaire Occitane).

These partners did not have as much experience with photovoltaic projects as Crédit Agricole. They had in fact never dealt with a collective photovoltaic project before, and as a result they were not equipped to appreciate the associated risk. What Unifergie considered as acceptable financial packages did not necessarily appear as such to its partners, who were discovering the specificities of mutualised projects with a particularly large and complex case. They therefore tended to be more cautious. As a banker explains, this constituted an additional difficulty.

> "So, we would not be able to take everything on, we will need to organise risk-sharing. Here, we encountered a second difficulty: what we had appreciated, within the Crédit Agricole group, as possible arrangements, raised more issues in our exchanges with other banks that had not been through out previous experience, which allowed us to use arrangements involving twenty farmers. They were discovering cases involving a hundred farmers." (Interview 34)[cciv]

Managing such a large and diverse group of partners was complex, especially as it involved negotiating a definition and a framing of risks that was acceptable to all. As the banker leading the syndicate loan noted:

> "a relation among six partners is more complicated, it takes more time, than a relation between two or three. So the management of decision processes in each of these establishments had to be coordinated, and we set up a steering committee with the client, with the supplier, to be able to explain what was going on within the banks, to be able to inform about progress of the case, the difficulties or constraints of one or the others" (Interview 34).[ccv]

Negotiations *among* bankers themselves were difficult, and it took a long time to coordinate investment decisions. As the case moved to the national level, the project was shifted to Parisian offices and considered by people who may have never set foot in Ségala Limargues, widening the gap between the SAS SAES and Tenesol's understanding of the project, on the one hand, and the (inscrutable to outsiders) world of finance and law, on the other. The kind of direct negotiations between interlocutors who knew one another relatively well and that farmers were used no longer applied.

> "And it's not easy among [banks]. Crédit Argciole is Crédit Agricole, but it was not Crédit Agricole lending in that case, it was its branch Unifergie […]. When you head up to Paris, when it is Unifergie, when it is a subsidiary branch, they no longer know anybody. You may as well be at the [Banque Populaire] or anywhere." (Interview 29)[ccvi]

Meanwhile, in Ségala Limargues, installation work had begun, with Tenesol working on credit. The project gained reality as systems were installed in the Lot, while bankers and lawyers in Parisian offices translated it into more and more abstract forms to incorporate it into their world. It was thus stretched across very different worlds, which generated tensions and heightened misunderstandings.

> "So there were many meetings, many fights. And then, it was not over. They gave us the green light on 14 July 2009. […] We had access to funding one year later. One year later, why? Because, because, an agreement of principle and then, here come the lawyers, everyone wants to mingle, everyone finds an issue… It was quite a ride!" (Interview 20)[ccvii]
>
> "In fact, to find money, banks dragged on for a long, long, long time. It was rather aberrant. They would always find a piece of paperwork, a pretext, something wrong. It delayed things, it delayed things, but we had already started everything." (Interview 28)[ccviii]

The SAS SAES and banks indeed did not move at the same rhythm. In Lacapelle-Marival, there was an urge to complete the project as quickly as possible in order to be sure to obtain the feed-in tariff and to be able to pay back the loans taken to bring in the initial capital stock. Tenesol, in spite of being a solid firm, needed to get paid at some point. On the other hand, within banking establishments, auditing the project was a long process that went beyond the mere validation that the SAS SAES had (perhaps naively) expected. Indeed, "once we had managed to coordinate loan decisions, the issue was not over, because we then had to coordinate the writing of the agreement, which took a while, since we were no longer among traders, but it was lawyers talking together within each banking establishment" (Interview 34).[ccix]

The first draft of the lending convention was written in March 2010. Negotiations then extended until mid-June under considerable and increasing pressure. The SAS SAES and Tenesol were asked to provide guarantees that they thought had been validated long ago and to reframe them in terms that suited the banking world.

> "They set up a syndicate loan, etc… Then, we intervened as Tenesol to present a contract between Tenesol and Sicaseli, as well as insurance contracts, maintenance contracts, validations from the controlling offices… A whole lot of things to provide. And of course, the contract we had signed with Sicaseli was not good enough for the bankers. Provisions were missing. So we had to change the contract. And it took quite a while, because there was a handover of power between Unifergie Toulouse and the Parisian headquarter, which wanted to, or had to, I don't know, take control over the project and kind of set the Toulouse offices aside. And the guys in Paris started sticking their nose in with lawyers, insurances, bankers, etc. And so it took a lot of time." (Interview 33)[ccx]

Each party seemed to have irreconcilable requirements, and Unifergie was torn apart between its responsibilities towards the agricultural world and its role as leader and arranger of the syndicated loan. In late March 2010, shortly after the first draft of the loan convention was sent, the president of the SAS SAES and the president of *Coopératives de France* wrote letters to all the banks involved in the project, trying to explain why mutualisation reduced the riskiness of the project, and arguing that since it was mutualised, it could not be considered the same as *any* photovoltaic project. They pushed for a rapid resolution of the issue. On the farmers' side as well, there had been a move to the national level. The exchange of letters that followed gives a good insight into the tensions and clashes of values at play during these months of harsh negotiations.

> "I would like to draw your attention to the exemplary approach in which the cooperative engaged with this project rooted in a territory, carried by a group of associated farmers who are financially involved to invest together in renewable energy." (Letter from Philippe Mangin, President of Coopératives de France, to the six members of the syndicated loan, 30/03/2010)[ccxi]

> "The installation of [photovoltaic] plants started in July 2009, on the basis of a financing agreement from the syndicated lenders. Eight months after the start, funds have still not been released and the financial terms have only just been communicated to the SAES. These are not acceptable and are even shocking considering current financial markets and the territorial approach adopted, which is driven deeply by a cooperative spirit. The agricultural world, which is going through a serious crisis, cannot understand that such a territorial and collective project may be treated by financial partners as any photovoltaic project where only the commercial margin obtained seems to matter." (Letter from the president of SAES to the president and CEO of Unifergie, 25/03/2010) [ccxii]

> "We understand that this project developed by the SAES is the outcome of a long and deep commitment of your Group in front of its members to meet their new expectations, and we would like to congratulate you on that.
> However, as you indicate it yourself, this project is onerous and complex – it involves 110 farmers, 220 buildings for about 66 0000 m^2 of panels and 7 MWc of installed capacity, and represents a total cost of 33.5 M€.
> Therefore, given its importance, this investment required the intervention of a syndicate loan articulated around our regional branch and Unifergie, difficult to constitute, entailing delays and lengthy discussions. We are working energetically on getting out of these, so as to complete this operation.
> We would like to point out that the conditions toward which we are heading (a little over 5%) legitimately correspond to this type of project, the complexity of which arises from its size (220 roofs), from the amount of funds to raise (27.5 M€ at the last stock-taking), and from the number of stakeholders (6 banks), each with their own legal and financial constraints.
> As of today, plant installation work is well under way, and we urge you to quickly find an agreement with all the financial partners, who might for some of them withdraw their support to the project." (Letter from Auxifip to the president of SAES 13/04/2010)[ccxiii]

The loan convention was eventually signed in June 2010. It took a day-long meeting after nearly three months of intense negotiations, held near the Champs-Elysées in Paris from 9 AM to 10 PM to finalise the texts and reach agreement on the last details. This last meeting, and especially the fact that it took place in Paris, miles from the SAES photovoltaic park – and, in a way, worlds away from it as well – to an extent enacted the displacement and transformations that the Sicaseli had gone through to take its project forward. It was now a player (however small) in the power sector, and one that was able to enrol bankers and negotiate loans of several million euros. As the president of the *Fermes de Figeac* noted, they had "discovered a new world".

> "We discovered an unfamiliar world, in which administrative complexity, distance from the real world, I would say, have consequences on their attitudes, on their thinking

> processes, exactly… We would never have thought so. People who cover themselves again and again, who have us conduct audits for things that we thought were evident…" (Interview 32)[ccxiv]

Throughout its many and sometimes trying detours, the photovoltaic project entangled itself to the feed-in tariff opportunity, but it did more than just that. By mutualising this opportunity – and adjusting the modalities of mutualisation to this new type of investment –, it transformed it into a powerful device that flung farmers into a new world and habilitated them to become renewable electricity producers in their way (a territorial, mutualised way in this specific case). Since then, the SAS SAES has changed its social objectives so as to be able to invest its profits in any kind of renewable energy projects without being limited to photovoltaics. The *Fermes de Figeac*, on the other hand, has now embraced renewable energy production as a full part of its activities, and is involved in several territorial renewable energy projects – biomass, wood fuel, wind energy and photovoltaics.

Conclusion

The project carried out by the *Fermes de Figeac* and the SAS SAES can be read as the successful translation of feed-in tariffs for photovoltaics into an opportunity and later a resource that was not only financial but also territorial. This was achieved through the constitution of a project and of a group promoting it. Following the material and procedural details of the project, I have shown that it hinged on the generosity of feed-in tariffs as well as on the flexibility offered by photovoltaic modules, but that it also transformed them, or at least re-interpreted them.

The farmers involved in the SAS SAES seized the photovoltaic feed-in tariff for what it was – an extremely interesting financial opportunity – but, through a specific mode of mutualisation rooted in the territory, they made more than just money out of it. They used feed-in tariffs for PV-generated electricity as a lever for entrepreneurial innovation which enabled them to develop new resources and expertise and to develop cooperative business models for the development of territorial renewable energy. But, precisely because they provided a way to build up new capacities, feed-in tariffs for PV-generated electricity also served as a device to maintain and renew a territorial agricultural and cooperative "tradition" currently threatened by decline. There is thus more to the SAES story than feed-in tariffs, but it would not have happened without feed-in tariffs.

The re-articulation of feed-in tariffs as *agencements* of modular photovoltaic technologies was at the core of the *Fermes de Figeac*'s project. In what ways does this case study inform the analysis developed throughout this dissertation?

First, the case of the *Fermes de Figeac* provides an example of the work required to benefit from the feed-in tariff opportunity. As outlined in previous chapters, feed-in tariffs work by framing an asymmetric transaction in which demand for photovoltaic electricity is bound and pre-framed, prices are determined at the state level, and supply of photovoltaic electricity is protected and unspecified. Feed-in tariffs then spell out a very attractive opportunity for potential photovoltaic electricity producers by guaranteeing the long-term profitability of photovoltaic projects. This feature was particularly prominent with the high feed-in tariffs for PV-generated electricity applicable in France between 2008 and 2010, which guaranteed extremely attractive, secured and profitable investments. Yet, the case study in this chapter shows that this advantageous framing was not enough to take advantage of the opportunity: a lot of work remained to be done to react to the incentive and to successfully reap the benefits promised by feed-in tariffs. This case thus confirms that entrepreneurship and opportunity-building are collective endeavours (Doganova, 2009; Doganova & Karnøe, 2014). The promoters of the photovoltaic projects had to go through several trials, including administrative procedure and material transformations, but they also had to convince their partners that the project was interesting. In other word, the security provided by feed-in tariffs for PV-generated electricity combined with mutualisation was not self-evident: it had to be translated in a way that convinced farmers, administrations, photovoltaic panel installers, and most of all bankers, which were certainly the hardest to enroll.

In the case of the SAS SAES, the outcome of these trials was the constitution of a new market and to an extent political agency structured by the requirements spelled out by the FIT scheme and by the constraints of mutualisation, as well as by the negotiations with partners. Crucially, the SAS SAES did not question or re-open feed-in tariffs nor photovoltaic modules; instead, they took them as they were and "plugged in" while making the most of the flexibility both provided. In other words, they re-entangled FITs and photovoltaic modules in a cooperative, mutualised manner that could benefit the territory and the farmers that live from it. This re-entanglement broadened the scope of feed-in tariffs for PV-generated electricity but did not divert or hijack them. It did result in the installation of photovoltaic electricity generation capacity, and, further than that, fostered the development of renewable energy locally, since it provided the cooperative with the financial, organisational and technical means to pursue other renewable energy projects. Feed-in tariffs functioned as a financial incentives; the *Fermes de Figeac* did not seek to enhance their profitability by disconnecting them from their original objective to promote renewable energy, but instead to make the most of them by building a synergy between the original objectives of feed-in tariffs and the objectives of the *Fermes de Figeac*. In that regard, the project remains limited in scope: it is not directed towards replication or proliferation, since it rooted in, and entangled to, a specific territory and a set of values.

In the end, as the gradual incorporation of photovoltaic systems in the farmers' routine seems to suggest, the photovoltaic systems installed by the SAS SAES were stabilised and pacified. They are now interfaces between the sun, the electric grid, the feed-in tariff and the farmers who benefit from them, and they are only activated insofar as they can bring additional resources to the cooperative and the territory – either financial resources, through the maximisation of production, or as a basis from which to launch other territorial renewable energy projects.

However, because they have been enmeshed in territorial and mutualised business models, both feed-in tariffs and photovoltaic systems have been slightly altered. They have triggered learning, contributed to the constitution of a new market actor and of new capacities, and been turned into not only financial but also territorial and to an extent political resources. Seen in that light, they have produced unintended effects, and have thus sparked a form of actualisation: the electricity produced and sold by the SAS SAES to an extent translates a specific articulation of resources, risks and profits, as well as a well-defined conception of the territory and of collective action. But this actualisation has by and large remained within institutionalised frames, which probably accounts for its success. It makes the most of feed-in tariffs for PV-generated electricity but at the scale of a single project and within the frame of well-defined objectives and values. In that, it carries no threat of proliferation, which distinguishes it from the kind of projects labelled as "speculative" that spread uncontrollably. A common feature of the projects considered as "speculative" or "disruptive" in interviews is indeed their disconnection from the objectives of the policy, from the reality of photovoltaics, and from the needs and specificities of the settings in which photovoltaic panels are installed (e.g. Interviews 14, 15, 17, 18). What seems to characterise "speculative" photovoltaic projects is the fact that they turn photovoltaic systems and photovoltaic electricity into passive intermediaries in financial constructions and take them into account for their financial potential only (interview 18).

This probably explains why public authorities consider this project as "exemplar" (interview 23). Had the feed-in tariffs scheme only triggered such projects, ambitious but limited in scope, the reaction of public authorities may well have been different. In that sense, the project of the *Fermes de Figeac* calls for comparisons with other projects that hinged on the modularity of photovoltaic and on the flexibility of feed-in tariffs but that overflowed and/or failed to fit in existing institutions and equipments instead of rearranging them. In particular, a focus on the motivations of the photovoltaic entrepreneurs that high FITs made emerge but did not sustain would help shed light on the specificities and shortfalls of FITs.

[xci] "Quelque part, je pense que les gens nous renvoient cette image… Elle n'est pas idyllique, hein. Il y a des fois des difficultés, tout ça, mais c'est vrai qu'on a mis – enfin, je crois qu'il y a, dans l'entreprise, une certaine âme. Les gens mettent… On a réécrit nos valeurs, c'est quoi nos valeurs, qu'est-ce qu'on défend… On n'est pas simplement du business. Il faut du business, mais…"

[xcii] "Contribuer dans la durée à la promotion d'une agriculture gestionnaire du vivant à haute valeur ajoutée, innovante et ouverte aux autres, pour participer depuis notre territoire à un développement durable au service de tous les hommes."

[xciii] "La solidarité collective, au service de la liberté des personnes, est le fondement de l'action de la coopérative ; Il n'y a pas de progrès sans respect de l'homme ; L'action n'a de sens que si elle s'inscrit dans la durée et la transmission ; Le respect du vivant et la passion de notre territoire sont à la base de notre professionnalisme ; L'ouverture aux autres et l'écoute de chacun est le gage de notre performance ; L'innovation est nécessaire pour faire vivre nos savoir-faire et notre culture."

[xciv] "Je n'aime pas trop me mettre devant, je préfère que le collectif, voilà, mettre les gens en situation de responsabilité. [...] Donc, je vais plus laisser s'exprimer les gens. Et puis, les dossiers, aussi, on met du temps. La question du temps revient, je pense ; la question du temps est importante. Quand un projet n'a pas l'unanimité, mais c'est qu'en fait, il y a quelque chose qui ne va pas. Donc on le retravaille, on le ramène, on essaye d'avoir le maximum d'adhésion. Je crois que c'est aussi une façon de travailler le collectif: chacun sa place, quoi."

[xcv] "[…] avec le recul, nous n'avons in fine que redonné du sens à l'esprit même de la coopération qui consiste à trouver ensemble des plus-values qu'on n'imaginait pas seul."

[xcvi] "Il faut nous adapter sans cesse. Nous ne pourrons durablement le faire qu'en mutualisant là encore un certain nombre de réponses. Le territoire nous unit définitivement."

[xcvii] "Comme on est enfermés dans un territoire et que c'est une volonté..."

[xcviii] "L'agriculture est évidemment un acteur essentiel du paysage, il est intéressant de montrer que ce dernier est bien le fruit d'une construction humaine et que nous avons besoin d'un monde agricole vivant pour le faire vivre."

[xcix] "D'ailleurs, un des enjeux de l'agriculture de ce secteur, c'est d'arriver à maintenir aussi une agriculture, parce qu'on conditionne le maintien de ce paysage."
[c] "La stratégie de notre conseil d'administration, c'est de garder une structure de proximité, proche des adhérents. Je sais pas si on va y arriver. Mais ce qui est sûr, c'est qu'on n'y arrivera que si on se lance à fond dans une stratégie de diversification, de métiers nouveaux, orientés vers ce qu'attend la société en fait: vers le développement durable, vers du produit de proximité, vers l'économie locale…"
[ci] "On n'est pas à l'abri de [se faire bouffer], aujourd'hui. Donc on met toute notre énergie à essayer de s'ancrer sur le territoire ; même si on se fait absorber, on sait que de toute façon, les projets de territoire ne vont pas disparaître."
[cii] "Tout ce qui est filière animale, en bovin, même les ovins – tout ce qui est animaux, même les porcs, tout… On est *mal*."
[ciii] "La difficulté, un peu, c'est que sur les marchés de quantités, le lait, la viande, on est en concurrence avec tous les pays européens, sur les mêmes prix, à peu près, on n'a pas les mêmes contraintes."
[civ] "Parce qu'on n'a pas vraiment d'avantages comparatifs sur notre territoire, on est en semi-montagne. Par rapport au bassin parisien, par rapport à la Bretagne, où il y a des filières très organisées, bon… là, on pèse pas."
[cv] "D'après ce qu'on a entendu, c'est vieillissant. C'est-à-dire qu'il y a beaucoup de personnes qui vont partir à la retraite, et y aura pas grand monde pour... pour reprendre les exploitations."
[cvi] "Parce qu'il y a un tissu local qui se construit, si on commence à le désagréger de partout – parce qu'aujourd'hui dans le bourg de Latronquière y a plus qu'une épicerie… Je pense que c'est dur, mais si tout le monde fuit ailleurs… au bout d'un moment, tout le monde va partir, quoi."
[cvii] "La Sicaseli par rapport à d'autres, a un territoire. […] On travaille sur ce secteur. Les agriculteurs baissent de 10-20% tous les 2 ou 3 ans, donc le marché agricole, enfin les ventes de la coop' en approvisionnement, vont baisser de plus en plus. Sans compter ceux qui viennent démarcher sur le terrain en plus. Et donc, faut trouver d'autres… d'autres revenus à côté, quoi."
[cviii] "Si rien n'est fait, l'agriculture est amenée à disparaître du territoire et avec elle non seulement une activité économique importante (environ 40 millions € de chiffre d'affaires produit par les exploitations agricoles), mais aussi toutes les aménités (qualité de l'eau, paysage ouvert, production d'énergie verte et captage de carbone par les prairies)."
[cix] "Et la volonté un peu folle de dire : on n'a qu'une solution pour s'en sortir, c'est de changer de cap. Changer de cap, eh bé, c'est imaginer tout ce qui est possible pour trouver des ressources – on a du soleil, on a du vent, on a de l'eau, on a de la biodiversité, on a..."
[cx] "Il faut arriver à trouver d'autres valeurs ajoutées, à la fois aux produits, et d'autres façons de s'organiser, ou d'autres ressources, pour arriver à maintenir une activité. Parce que s'il y a pas d'activité et s'il y a pas d'hommes qui entretiennent le pays, au bout d'un moment, le pays… il perd de son attractivité, en fait."
[cxi] "La Sicaseli s'est en effet construite en même temps que son territoire, profitant de ses avancées et l'aidant en recherchant continuellement des innovations."
[cxii] "Et plus on développera des choses comme ça, plus ça fera du travail sur le secteur. Le but de la coop', c'est ça. C'est d'amener le plus d'argent au territoire, et faire travailler de plus en plus de personnes. […] Si on vend juste des produits… y en a assez qui le font."
[cxiii] "Quelque part, on est un peu obligés de rechercher de nouveaux métiers, et ça a été un peu l'idée originale qui a poussé notre coopérative à lancer une espèce de veille active autour des nouveaux métiers, autour de l'énergie, autour des bio-prestations…"
[cxiv] "On a une stratégie aussi, depuis toujours : on est curieux. Donc on voyage beaucoup. Donc on a été au Brésil, en Allemagne, au Japon, en Pologne, en Italie, en Tunisie… On a été un peu partout, tous les deux ans on fait des voyages. On se renseigne."
[cxv] "On essaye de s'imprégner de ce qui est positif, pour essayer d'en faire un autre projet."
[cxvi] "Quand on a des preuves scientifiques, ou sur les papiers comme ça, ben il faut travailler avec des gens crédibles, je veux dire. Vous travaillez avec l'agence de l'eau, vous travaillez avec... et

maintenant, bon, quand on commence à mettre les pieds un peu partout... Après y a des références, après on amène ça sur un plateau... Des fois ça passe."
[cxvii] "On est sur la durée, hein. Il faut redonner du sens au long terme. Ca, c'est très… Enfin, il me semble que c'est important. Même si après, comme tout bouge tout le temps, il faut – il y a cet aspect réactivité qui entre en jeu. Il faut être prêt quand ça va, mais il faut mettre des caps et il faut construire dans la durée."
[cxviii] "On a identifié depuis... Oh, plus de dix ans, début des années 2000, que la question de l'énergie était au centre de nos préoccupations, et qu'on pouvait en faire un atout. Donc, sans forcément qu'on pense au solaire en particulier, on a créé une petite cellule de veille, d'innovation, et on a organisé plusieurs visites."
[cxix] "Puis un jour, moi j'avais été dans un séminaire, j'étais à Fribourg et puis je vois des toits photovoltaïques, je vois ce que fait Fribourg dans ces démarches de développement durable. J'y retourne avec mon président, je lui dis : il y a quelque chose qui se passe. Et puis après on fait un voyage de conseil d'administration"
[cxx] "On avait une jardinerie, on a fait un toit, plus ou moins bien. […] Mais on se dit, y a quelque chose à creuser. Et puis, l'opportunité, avec le passage à 60 centimes… On se dit, aaah, putain, ça vaut le coup quand même de proposer à nos agriculteurs. Les quelques premiers mois, on cherche à se positionner pour vendre les toits, et puis comme on a une stratégie coopérative et qu'on se balade, un jour on était dans l'Aveyron, on a vu un modèle monté par les Aveyronnais – et là, ça a fait déclic en disant : 'c'est ça qu'il nous faut.' "
[cxxi] "A partir du moment où on commence à parler des toits photovoltaïques, et qu'il y a eu un lancement de projet au niveau politique, et d'un prix et un seuil de rentabilité, tout d'un coup ! tac, ça interpelle. Alors, de là, y a plein de sociétés qui se sont mises en place. Automatiquement, tout ceux qui avaient des toits un peu conséquents, on a été sollicités. On a eu des appels téléphoniques, ou des trucs : vous avez un toit, ça vous intéresserait pas de louer le toit, de-ci, de-là. De là est venue la réflexion de groupe de dire : mais pourquoi nous on le ferait pas?"
[cxxii] "Y a eu un démarchage de la part de certaines sociétés qui proposaient ou de la location de toitures, ou bien la fabrication de hangars couverts de panneaux avec gratuité du hangar pendant… Le hangar nous appartenait au bout de 25 ou 30 ans. Donc moi ça m'a mis la puce à l'oreille, je me suis dit, tiens, si y a des gens qui s'intéressent à vouloir louer mon toit ou à me construire quelque chose gratuitement, je me suis dit, c'est qu'il doit y avoir un petit quelque chose dessous… Donc voilà, entre autres un jour, on a eu une réunion au niveau de la Sicaseli et puis… Le projet a commencé comme ça, quoi : à la première discussion, oui ça serait peut-être intéressant."
[cxxiii] "Et je sais pas ce qu'il s'est passé, toujours est-il que quelques jours plus tard, même pas une semaine après, une société basée à Bordeaux m'a contacté – alors je sais pas s'il y avait quelqu'un dans la salle, s'il y a eu des transmissions, je sais pas – m'a contacté pour me louer mes toits. Alors là de nouveau, je leur ai refait faire une étude, et… ils se proposaient de me louer tous mes toits pour 8 euros du mètre carré. Voilà. C'est vrai que ça paraissait, comme ça, attractif: vous louez les toits et puis vous avez que ça à faire. Donc moi, j'ai dit, ben… j'étais partant là-dessus, je partais – l'idée de partir dessus me satisfaisait, parce que moi j'avais pas d'investissements. Moi j'avais un souci quand même, un petit peu, c'est que je connaissais pas les gens, je savais pas où j'allais, j'étais tout seul, un petit particulier individuel par rapport à une structure que je connaissais ni de nom ni de quoi que ce soit."
[cxxiv] "Du coup, quand on a proposé ce montage, l'objectif était de réunir un maximum de personnes, pas pour faire le plus gros projet, mais surtout pour permettre à tous types d'agriculteurs d'en profiter, pas simplement les gros. Donc des gens qui n'avaient pas forcément le temps ou la compétence de décortiquer un devis photovoltaïque, parce que bon, c'est pas compliqué, mais pour comprendre un devis photovoltaïque d'un bâtiment, si on veut être sûr de pas se faire avoir, il faut avoir un minimum d'informations."
[cxxv] "On a eu peur, un peu, parce qu'on s'est vite rendu compte que les engagements financiers – qu'on prenait des risques pour la structure. On s'est dit, si ça marche, ça ira, si ça se plante… [...]

Mais on s'est dit quand même, il faut y aller. Il faut y aller. Il faut y aller, et on ne peut y aller que par une démarche collective en mettant des règles un peu politiques de départ."

cxxvi "Pour être honnête, Laurent nous a embarqué un peu. Laurent s'est passionné et nous a embarqué. Mais le président s'est passionné aussi, il y a cru. Moi… j'étais d'accord mais je freinais un peu parce que les montants astronomiques me faisaient peur de craquer. Tout en cautionnant, je faisais gaffe, je mettais la prudence. Et puis comme une majorité d'agriculteurs du conseil d'administration qui avaient des toits trouvaient le projet intéressant, ils nous ont poussé."

cxxvii "Déjà en interne au niveau de la coopérative, bon, y a eu débat quand même. […] Donc j'avoue que ça a été assez tendu, parce que moi j'y croyais beaucoup, donc c'est pour ça que je me suis battu pour le faire, mais c'était pas partagé par tout le monde."

cxxviii "[C'est Laurent Causse] qui s'est vraiment accroché pour que le projet naisse. [...] Y en a pas beaucoup, non, qui ne voulaient pas y aller, mais il fallait quand même quelqu'un qui ait de la poigne, qui lâche pas face aux contraintes. Et lui, c'était la bonne personne."

cxxix "Il faut oser, quoi. Je pense qu'à un moment il faut un peu de culot. Mais après, ceux qui étaient au conseil d'administration c'est des gens qui sont je veux dire, plutôt des fonceurs et voilà quoi. Faut y aller. On avance et puis… on apprend."

cxxx "Alors en fait c'est assez surprenant, on en a parlé une fois ou deux en conseil d'administration, plusieurs personnes disent: tiens, c'est pas bête, c'est pas bête. On pense que c'est un projet qui peut intéresser, et on fait un appel. Et on invite tous les gens dans une salle des fêtes. On pensait avoir 50 personnes, y en avait 350. Ca, ça a été la grosse surprise. […] Quand on fait une réunion aujourd'hui pour du développement agricole, on fait cinq rappels, on a vingt personnes. Là, qu'est-ce qu'il se passe? Les mêmes agriculteurs, on leur envoie un papier pour des toits photovoltaïques, ils savent pas ce que ça veut dire, ils viennent à 350."

cxxxi "Ils avaient lancé une réunion comme ça, à tout le monde. Tous les agriculteurs d'ici, du coin; tous les adhérents de la coopérative. Il avait envoyé un courrier, comme ça ; un peu le même qu'on a eu aujourd'hui. […] Et en demandant s'il y avait des gens intéressés. Il avait fait ça dans une salle petite, elle était pleine, et même on n'arrivait pas à fermer la porte tellement les gens étaient intéressés. […] Moi, j'aurais jamais cru que les gens se seraient intéressés comme ça au solaire."

cxxxii "On s'attendait pas du tout à ce retour-là des agriculteurs. Il y avait un retour très fort parce que, un, les gens faisaient confiance à la coopérative, et on leur proposait quelque chose de clé en main. Il faisaient confiance et ils n'avaient rien à faire."

cxxxiii "[Sans le projet de la Sicaseli,] il y en a pas beaucoup qui se seraient lancés. Il y en aurait eu quelques uns. Il y en aurait même pas eu 10%. Peut-être 2-3%. C'est tout. Je sais pas. Moi je sais pas. Ca me titillait, oui, mais... [...] Là, de suite, j'ai accroché à cette idée de groupe et tout ça, et de mener quelque chose... Je suis pas sûr que j'aurais franchi le pas. Ou alors, si je l'avais fait, je me demande s'il aurait pas été trop tard. Parce qu'il fallait réagir, hein !"

cxxxiv "Non, individuellement non. Non, parce que... Y en a qui se sont lancés individuellement, et je vois, quand il y a des problèmes avec ERDF, soit les raccordements, soit après qu'ils payent pas les factures et tout ça, quand il y a qu'un gars... Tandis que là, comme on est un groupe, bon, si c'est pas payé, si ça retard de 6 mois sur deux ou trois dossiers, le reste rentre. Ca compense. C'est un ensemble. Puis des projets comme ça, se lancer tout seul... Nous on avait entre 1200 et 1300 m^2... et l'investissement... les banques peut-être auraient pas suivi, premièrement. Et bon... Tandis que quand on a que 20% comme ça, ça passe."

cxxxv "Donc moi j'étais partant de suite, parce que je me suis dit – seul, je ne l'aurais pas fait, en société, je me suis dit, on limite quand même les risques, donc j'ai dit, pourquoi pas. [...] Mais c'est surtout le fait d'être en société qui m'a... seul, je vous dis, je ne l'aurais pas fait, parce que bon, il y avait quand même des prises de risques importantes. Parce que là, quand même... les prises de risques sont moins importantes, et puis, et puis, le projet monté dans une globalité avec une surface importante a fait qu'on a pu obtenir de certains des fournisseurs et tout ça des engagements qu'on n'aurait pas obtenus tous seuls, quoi. Voilà ma première motivation."

[cxxxvi] “Dès que ça a démarré, je me suis dit, il y a quelque chose à faire, là. Moi je voulais le faire, et j’ai même fait faire des devis en propre. Par contre, quand j’ai vu les devis, je me suis fait un peu peur. Parce que partir tout seul... du coup, je l’ai pas senti, parce que ça faisait des sommes faramineuses.”
[cxxxvii] “Bon, là il y a eu 110 projets, il y en a plus techniquement, mais il y a eu 110 projets, ou 109 agriculteurs ; sur ces 109, il y en aurait, objectivement, s’ils l’avaient fait seuls, simplement une quinzaine qui l’auraient fait.”
[cxxxviii] “Beaucoup d’agriculteurs ne pouvaient pas avoir le financement directement. Beaucoup se seraient découragés s’ils l’avaient fait tout seuls.”
[cxxxix] “C’est une assoc’ qui fait 2000 ingénieurs dans la région, et habituellement ils avaient 10-15 personnes. Et là, le gars me dit, ouais, ben on sera sans doute une quinzaine, un truc comme ça. Je lui dis, attention, c’est un sujet d’actualité, il peut y avoir plus de monde. […] Donc, la réunion qui devait se passer dans un premier temps dans le petit bureau de Tenesol, où on pouvait accueillir 30 personnes, est partie se dérouler à Blagnac, dans un amphithéâtre, et puis finalement on l’a ramenée chez Tenesol en louant un barnum. Et là, on avait 230 personnes.”
[cxl] “Donc, il y avait la possibilité de faire une SARL, une SA, une SAS. Vu le nombre – ils sont, je sais plus maintenant combien, 130-140 à peu près – une SARL c’était trop lourd. Et comme ce projet était porté par la coopérative, ils voulaient fonctionner un petit peu comme une coopérative. Et la SAS, avec un président, un conseil d’administration, c’est un peu ce même fonctionnement. Donc ça leur a plu tout de suite, la SAS. Mais pour autant, ils voulaient pas faire une coopérative, quand même, parce que là il y a des investissements très importants qui reviendront ensuite au propriétaire par le biais du bail emphytéotique gratuitement. Donc, voilà. C’est ce fonctionnement type coopérative, avec président et conseil d’administration, qui leur a plu.”
[cxli] “D’une part, la transparence, par des assemblées générales et un conseil d’administration, même si ça a été un peu coopté au départ, on a fait une douzaine de personnes, motivées sur ces questions là, un peu divers dans la répartition géographique et dans les origines – ça n’était pas simplement des administrateurs des Fermes de Figeac, ils étaient même minoritaires, d’ailleurs.”
[cxlii] “[…] Il est précisé que, seuls peuvent être actionnaires de la SAS SAES, des personnes qui sont liées à un bâtiment sur lequel la SAS SAES a accepté de mettre en place des panneaux photovoltaïques.”
[cxliii] “Les actions de la société ne peuvent être cédés y compris entre actionnaires qu’après agrément préalable donné par décision du conseil d’administration”
[cxliv] “J’ai vraiment soutenu cette démarche-là à titre personnel, c’est-à-dire, d’une part, de la rigueur – de la rigueur technique et de la compétence, bien tout vérifier; une solidarité entre les gens, mais qui n’est valable, efficace que s’il y a une grande transparence. Donc ça a été ces trois éléments. De la transparence, de la solidarité – de la mutualisation – et de la compétence et de l’efficacité. C’était ces trois points là qu’on a essayé de mettre en œuvre.”
[cxlv] “Mais je crois que, par le fait qu’on ait gardé le même cap, autour de l’enjeu stratégique de l’énergie et de la posture de dire: ‘on n’y arrivera que si on a une démarche collective et mutualisée’, ces pôles nous ont permis de garder ce cap, de garder cette vision, et d’aboutir.”
[cxlvi] “Dès le départ, moi, j’ai souhaité, vraiment, on est transparents. Je me souviens bien les premières réunions: voilà, c’est pas sûr qu’on y arrive, y aura des emmerdes, voilà, mais vous serez au courant. Chaque fois. Après, on prendra des décisions, parce qu’il faut les prendre, mais ça m’a paru quelque chose de très important, plutôt que de dire : “on s’occupe de tout”. Ca, ça me plait pas. Parce qu’au bout d’un moment, les gens, ça crée de la… voilà, 1), c’est qu’ils ne nous disent pas tout, 2) ils peuvent s’en mettre plein les poches et puis on sait pas, 3) c’est par intérêt, et puis vous cassez la dynamique.”
[cxlvii] “- viser un coût de revient au Wc le plus faible possible (kit…) et fiabilité du matériel dans la durée ; - système adapté aux bâtiments d’élevage ; - option pour la dépose de l’ancienne couverture et la pose de la sous-couverture.”
[cxlviii] “On a vu de tout, hein. On a vu des gars que… pfff!”

[cxlix] "On a vite senti, même moi qui suis pas du tout du milieu, du business ni tout ça, j'ai senti que c'était des gars pour faire un coup de poker et…"
[cl] "On a fait confiance à Laurent pour tout, en fait. En grosse partie. Nous on a pris les grandes décisions, les grandes lignes droites, et c'est lui qui s'est occupé de la grosse partie des choses: convoquer les vendeurs de panneaux, et puis se coordonner avec ERDF parce qu'il y avait quand même du boulot."
[cli] "Un projet comme ça, ça se met pas en place comme ça. Il y a l'aspect financier, l'aspect technique, l'aspect juridique. Nous, on était là pour fédérer tout ce monde. Chaque fois qu'on avait besoin d'une compétence, on allait la chercher."
[clii] "Nous, agriculteurs, on a dit sur les bâtiments qu'on pensait mettre des panneaux. Après, il y a eu une étude, qui a été faite par la Sicaseli, et il en est ressorti une étude – bon, ils ont pris certains bâtiments – comme nous, ils nous ont pris tous les bâtiments qui étaient – tous les nouveaux bâtiments qui étaient construits en, je sais pas comment dire moi, en matériaux modernes."
[cliii] "Il y a eu plus de demandes, mais bon, il y avait quelques toits qui avaient été éliminés parce qu'ils étaient mal exposés. Moi j'en avais demandé deux autres, de toits qui étaient… les toits étaient bien exposés, mais les charpentes étaient pas assez costauds pour soutenir le poids des [modules] photovoltaïques."
[cliv] "On a exclu des gens, voilà, parce que la charpente était un peu trop juste, on n'a pas eu les validations techniques, donc, voilà. Mais on a pu faire de l'arbitraire et de la rigueur parce qu'on avait de la transparence après derrière. C'est le principe."
[clv] "Il y avait des personnes qui étaient embêtées parce qu'il y avait des bâtiments qui étaient en indivision et bon, c'était carrément la panique; enfin pour arranger tout ça. Ca fait qu'il y avait d'autres bâtiments qui ont sauté."
[clvi] "Après, il y a eu peut-être quelques éliminés aussi par rapport aux distances entre la production EDF et la toiture. […] Puis après, ben, c'est sûr qu'il y a eu l'aspect financier aussi qui a éliminé – très peu, je pense."
[clvii] "C'était un peu compliqué, parce que bien souvent, le propriétaire est donc une personne physique, le bâtiment servant de support à la centrale est construit par peut-être l'agriculteur à titre individuel ou la société dans laquelle il est agriculteur, et il y a un troisième, en quelque sorte, utilisateur qui est la société SAES pour la toiture. Donc on a finalement trois propriétaires à trois niveaux différents, comme un immeuble de trois étages."
[clviii] "On a fait venir des géomètres, ils ont mesuré les toits, et ils louent la partie où il y a des panneaux solaires. Il faut d'ailleurs que ce soit comme ça. Comme ça, c'est eux qui perçoivent l'argent d'EDF, c'est eux qui peuvent faire les facturations… voilà. Ca nous libère vachement de choses, parce que nous, les actionnaires, on n'a rien à faire en fait."
[clix] "On peut louer l'intérieur du bâtiment au GAEC, et la toiture est louée à la SAES. Ca a été divisé en volume, si vous voulez. Les toits restent privés."
[clx] "Mais au départ, j'aurais jamais imaginé que pour louer comme ça, il fallait faire une division volumétrique des bâtiments. Ca veut dire que j'ai mon bâtiment, chaque bâtiment, 380A c'est le bas et 380B, c'est le toit. C'est marrant, on le voit même sur le cadastre, parce que les cadastres sont actualisés. On voit les bâtiments qui ont été divisés volumétriquement. C'est assez marrant."
[clxi] "A un moment donné, on s'est posé la question de savoir si le prix de loyer pouvait remettre en question la nature du contrat : est-ce que le contrat de bail emphytéotique un jour ne peut pas être remis en question et reclassé comme bail à construction ?"
[clxii] "Il y a eu quand même une clause, aussi, c'est que la personne qui faisait le projet était propriétaire du bâtiment et du terrain. C'est ce qu'on voulait. Les notaires ont été contents dans le secteur, parce qu'il y a des arrangements de familles qui se sont faits. Du coup, ça a débloqué pas mal de situations. Il y a des gens qui ont fait des arrangements de familles…"
[clxiii] "[Les baux] c'était fastidieux parce qu'il a fallu trouver l'origine de propriété, les actes… c'était compliqué de savoir qui était le vrai propriétaire, c'est toujours pareil, du bâtiment. Et quand on leur disait aux agriculteurs: 'le bâtiment il appartient à madame parce que madame est

propriétaire du terrain', dans un monde un peu macho, ça passait très mal, hein… Donc c'est madame qui allait signer le bail et encaisser le loyer, donc ils ont tout de suite fait la relation, si madame s'en va, je n'aurais plus ce loyer, ouhlalalala."

[clxiv] "J'ai animé quelques réunions où il a fallu expliquer aux agriculteurs les incidences fiscales et sociales de ces revenus complémentaires liés au photovoltaïque. Parce que là, c'est complexe, effectivement. Ca dépend de la situation de chacun. C'est-à-dire que ces revenus photovoltaïques, c'est-à-dire les dividendes de la société, ne seront pas fiscalisés de la même façon si l'agriculteur est à titre individuel, s'il est en société, s'il est au bénéfice agricole forfaitaire, s'il est au bénéfice agricole réel. Et, pour par exemple ceux qui sont au bénéfice agricole réel, ça rentre dans le calcul de leur cotisation sociale. Alors, il a fallu articuler tout ça et préciser tout ça. Ca a engendré quelques modifications. Par exemple, un agriculteur à titre individuel a été amené à faire une société, justement pour que les dividendes de la SAS ne rentrent pas dans sont activité agricole mais à titre personnel, donc ne soient pas soumis à cotisation sociale. C'était toutes ces articulations qu'il fallait faire au cas par cas."

[clxv][clxv] "[Tenesol] se sont occupés de tout. Ils ont installé, ils nous ont livré la centrale clé en main. Par contre, c'est nous qui nous sommes occupés de tout ce qui était administratif. Ils n'ont pas fait les dossiers administratifs; ça, on l'a gardé. Parce qu'à mon sens, c'était trop important. Faut pas le confier à quelqu'un au risque de tout perdre. Pour moi, c'était clair qu'il fallait qu'on garde ça. Et avec le recul, on a eu raison. Si on reste dépendant d'un tiers comme ça… on a beau se fâcher au téléphone, mais si le gars fait pas son boulot, il fait pas le boulot."

[clxvi] "Alors, imaginez, à Lacapelle, là-bas dans les bureaux, Sylvain, Laurent, une secrétaire; 115 dossiers individuels. […] On envoie le dossier à EDF, ils le renvoient avec un tampon, on valide, ça revient. Ca repart. Quand il manque quelque chose, hop, il faut revenir au même endroit… Enfin, imaginez, pour avoir les accords, les agréments, le nombre de navettes qu'il y a eu avec les dossiers."

[clxvii] "Les dossiers étaient ce qu'on appelle 'qualifiés', déclarés recevables. Ensuite, on fait des études, on établit ce qu'on appelle une proposition technique et financière. Donc ça, les bureaux d'études l'établissaient, moi ça m'appartenait à l'époque de les valider. Ensuite, on fait des études plus précises une fois que la PTF, cette proposition technique et financière, que cette offre de raccordement est acceptée. On fait une étude plus précise en disant: voilà, on va poser le câble à tel endroit, ça va coûter tant. On établit ensuite un document contractuel qui a la durée de vie du site, c'est-à-dire une convention de raccordement qui dit : voilà, le raccordement du site de M. Untel nécessite la pose de tant de mètres de câbles, de telle section, la limite de propriété est à tel endroit, le comptage sera de tel type, etc… Donc ça fait partie des documents d'accès au réseau. Il y a d'une part la convention de raccordement; ensuite, il y a ce qu'on appelle le CARD, contrat d'accès au réseau de distribution pour injection. Donc, c'est en fait que le producteur puisse accéder au réseau pour livrer son énergie. La convention d'exploitation, qui définit les règles en particulier en matière de sécurité, puisqu'en fait une installation de production, elle peut renvoyer de l'électricité sur le réseau, donc si on a un incident il faut qu'on sache de qui elle vient. Et tout ça, ça fait partie de ce qu'on appelle les dispositifs contractuels d'accès au réseau, donc ça veut dire des paiements, des signatures, etc… Et après, on met en service dès lors qu'on sait que le producteur a ce qu'on appelle un responsable d'équilibre, c'est-à-dire quelqu'un pour acheter son énergie."

[clxviii] "Et ERDF c'est pareil. Ils nous connaissaient. Donc on a pu discuter. A un moment donné, il y avait un truc qui était complètement aberrant, on est allé les voir, on a discuté, on a arrangé les choses."

[clxix] "On s'est rencontré à plusieurs reprises pour leur délivrer *les* certificats, et en l'occurrence, vu le nombre d'installations, il valait mieux qu'on se voit avant pour optimiser les délais de traitement desdits certificats, parce que ce qu'il leur fallait c'est pas un certificat, un certificat au fur et à mesure. C'est qu'ils voulaient avoir la totalité des certificats avant de commencer. Bon. Donc on leur a fait une opération un peu spéciale pour le certificat ouvrant droit à l'obligation d'achat."

clxx “Sachant qu’avec EDF, impossible d’avoir un interlocuteur. On a demandé à avoir un interlocuteur – vu la taille du projet, au départ, on avait demandé à avoir un numéro de téléphone, une personne, il y a un souci, dites-nous. Pas possible. Ca n’a pas été possible. Donc imaginez les navettes qu’il a fallu faire… Enfin, moi je l’ai pas vu tout ça. Mais chaque fois qu’on était en conseil d’administration, ils nous expliquaient: bon voilà, sur 115 dossiers, il y en a 40 qui sont dans cet état d’avancement, il y en a 30 qui sont là, il y en a 10 qui sont à ce niveau d’avancement...”

clxxi “Il y avait vraiment un discours de gens qui ne se comprennent pas. Tout simplement parce qu’il y en a un qui était sur le chantier et qui gérait les merdes du quotidien, et qui comprenait pas qu’il fallait que ça rentre dans un tableau Excel, pour des questions de trésorerie, pour des questions de financement, etc… et l’autre qui avait son tableau Excel et qui pigeait pas que… ben, la boîte est pas venue, donc ouais, les panneaux ils sont toujours en bas sur le terrain.”

clxxii “On a choisi un fournisseur qui s’appelle Tenesol, et d’ailleurs qui n’était pas prêt du tout, qu’on a fait évoluer aussi. Parce que la première proposition qu’ils nous faisaient ne nous plaisait pas du tout. Ils n’étaient pas du tout adaptés à notre système.”

clxxiii “Je me suis battu plus en interne qu’avec lui, parce que chez moi ils voulaient pas le faire, le projet. Tenesol, c’est une belle boîte, mais c’était une boîte qui n’était pas très courageuse, on va dire. Pas très prise de risque. […] Et moi j’ai pas voulu lâcher, parce que j’avais pour objectif que [l’agence Sud-Ouest] devienne grosse […] et je me suis dit: il faut que je choppe de gros projets pour que ça aille vite, sinon…”

clxxiv “On avait réussi à, pas créer une complicité, mais on avait réussi à construire le projet ensemble, même en étant client/fournisseur et en s’affrontant, parce que, forcément, il y a des affrontements.”

clxxv “Imaginez-vous, pour mettre 55 000 mètres carrés – découvrir 55 000 mètres carrés de toiture, recouvrir avec 55 000 mètres carrés de panneaux photovoltaïques ! Le personnel Ténésol n’était pas en mesure de – ils n’avaient pas le personnel pour le faire. Personne avait le personnel pour le faire. On a contacté tous les charpentiers du coin.”

clxxvi “Et puis les branchements… Parce que ce qu’on a oublié de vous dire aussi, c’est que, nous, c’était raccordable début juillet 2010. Jacques Calmejane, il a été raccordé au mois d’août, fin août. Nous, on a été raccordés au mois d’octobre pour le petit. Et le gros, il n’a été raccordé qu’au mois de janvier-février de l’année d’après! Alors, vous vous rendez compte de la production que vous loupez! Vous êtes prêts à produire, et puis vous pouvez pas injecter dans le circuit!”

clxxvii “Si la partie administrative des dossiers a été longue et complexe, sur le terrain, les interventions d’ERDF jusqu’à la mise en service des centrales ont été pénalisées par la complexité des dossiers et l’afflux de demandes de raccordements photovoltaïques”

clxxviii “Le raccordement ERDF, nous […] il a été bien six mois après la fin des travaux. Bien. Ca a tardé. […] Ils en ont beaucoup fait au mois de juillet-août, parce qu’on a eu la chance – enfin la chance, chance et malchance – d’avoir une sécheresse en 2010 […]. Alors, ils avaient les barrages hydroélectriques, là. Et en juillet-août, ils ont branché tous les bâtiments qui étaient prêts, ils les ont branché, en quinze jours ils ont tout branché. Pour pallier, quoi. […] Ils vidaient les barrages la nuit, et ils employaient l’électricité photovoltaïque le jour, quoi. C’est ça qui nous a aidé.”

clxxix “Aujourd’hui, on a développé notre propre outil, qui est unique d’ailleurs. Parce que comme on est dans un secteur assez groupé, on compare les centrales les unes par rapports aux autres; et dès qu’il y a une centrale qui décroche, on se dit qu’il y a un problème. Quand on voit une centrale isolée comme ça, elle produit moins, on sait pas si c’est parce qu’il y a un nuage qui est passé ou si… Tandis que là, **on le voit.** En général, c’est parce qu’elle se salit plus vite que les autres. Mais c’est arrivé qu’on ait des petits soucis. Il n’y avait pas d’alarme sur la centrale, mais il y avait une moindre production; et le fait de pouvoir comparer avec les autres centrales d’à côté, ça nous permet d’avoir des éléments assez fiables.”

clxxx “Enfin, on a monté un système de SMS et tout ça, ensemble. Parce que maintenant, tous les toits sont raccordés à Lacapelle-Marival. Tous les matins, y a un gars, même Laurent, il regarde pour savoir si ça fonctionne bien.”

[clxxxi] “[…] on est un peu impliqués comme ça, on est agriculteurs – enfin, c’est notre intérêt que ça marche [...]. Là, [les panneaux] sont faciles à voir, au bâtiment d’en bas. Quand on arrive, y a tous les onduleurs dehors, là, en passant on va voir s’ils sont allumés, quoi. S’il y en a un qui est allumé, on appelle.”
[clxxxii] “Au début, tout le monde était content, y en avait même, ils avaient pris un cahier, tous les jours, ils notaient, la production de tous les jours. Et... là, j’en ai parlé avec un copain, là, il me dit : ‘j’ai arrêté, parce que j’en ai marre tous les d’aller voir si ça marche ou pas.’ [...] Je m’en suis douté, parce que sur 20 ans ça fait long, quand même. Aller voir tous les matins... on va voir de temps en temps. [...] Moi aussi je le notais une fois tous les 15 jours, mais j’ai arrêté. Non, non, on regarde que ça marche, et puis après... ”
[clxxxiii] “C’est marrant, parce qu’on est quand même sur la partie est du département, et c’est vrai qu’on voit maintenant une différence assez sensible entre les zones. Et en fait, il se trouve que c’est la zone nord qui produit le plus, parce qu’en fait elle est en altitude. Les zones en altitudes sont plus ensoleillées, moins de brume l’hiver, il y a plus de fraîcheur aussi, ce qui fait que globalement, ça produit mieux.”
[clxxxiv] “La meilleure chose qu’on ait faite, c’est de garder la maintenance. Parce que du fait qu’on a la maintenance, on se contente pas d’arriver à un objectif. […] Mais le gars qui fait la maintenance, il cherche toujours à optimiser. Alors de ce fait… par ce que ces petits pourcentages en plus, c’est ce qui fait toute la différence.”
“Parce qu’on voit bien que ce qui fait la différence, c’est les 3-4% de plus qui font le résultat, très souvent. Et ces 3 ou 4% de plus, il faut aller les chercher. Et c’est la proximité, la compétence et la réactivité, que n’ont pas… - Et c’est une force du collectif, c’est qu’on a le périmètre adapté pour pouvoir proposer cette maintenance là. Objectivement, ça, c’est un élément déterminant.”
[clxxxv] “Quand vous êtes au mois de mai, aux jours les plus longs où ça crache plein pneu, là il faut pas se louper. Parce que même si vous repédalez derrière après, vous rattrapez pas. Il faut être super réactif, quoi.”
[clxxxvi] “C’était une technique nouvelle, le photovoltaïque, on n’a pas beaucoup de recul. Qui dit nouveauté dit, forcément, inconnu, donc risque non maîtrisé, et toute la difficulté a été de comprendre cette mécanique, de comprendre le risque, de voir s’il y avait un risque, si c’était cohérent… Voilà, quel niveau de risque on prenait.”
[clxxxvii] “Si vous voulez, c’était un cas de figure spécifique, parce que d’une part, la rentabilité y était. C’était indéniable. On n’avait pas de recul, mais enfin on avait du recul en Allemagne par exemple. Mais les banquiers – et les agriculteurs eux-mêmes – n’étaient pas habitués à ce que ça produise sans travail, et à ce que ça dépende donc d’un élément extérieur, le soleil, qui est présent tout le temps. Donc ils ont voulu se voiler la face, à mon avis, à cause de ça.”
[clxxxviii] “Alors, aujourd’hui, on a été quand même dans le business plan très sécurisé. Donc on était partis sur des niveaux de ressource énergétique à 1020, donc c’était relativement sécurisant.”
[clxxxix] “Donc en fait, il y a trois périodes. Un, démarrage et installation. Après, pendant une douzaine d’années, [l’agriculteur] n’a pas grand chose en net, parce qu’il doit rembourser les emprunts, la société doit rembourser les emprunts. Et après, ça monte très vite. On se retrouve à partir des années 13, 14, 15 avec des niveaux de rémunérations qui dépassent les 50€ par mètre carré. Et en moyenne, ça fait 20 €/m2/an. Ca, c’était la prévision.”
[cxc] “Je dirais que sur la dimension financière, c’était important que les… le projet a permis à des gens qui financièrement n’avaient pas forcément les moyens de le faire de le faire. Ca a été ça l’idée de départ. Avec, même si je ne devrais pas le dire auprès des banquiers, un financement à 100%.”
[cxci] “Il y a eu un montage financier très intéressant qui fait qu’ils ont eu besoin d’apporter 20% de la somme en auto-financement – alors, bon, pas forcément en auto-investissement, ils l’ont eux-mêmes emprunté, mais ils n’ont eu à financer que 20% de l’investissement, les 80% étant finances par la société [SAS SAES] directement. Donc, ça a permis à ces éleveurs de moutons, qui ne sont pas fortunés, de pouvoir diversifier leurs sources de revenus tout de suite. Et si ça leur apporte, pour certains qui ont fait des petites installations, que quatre ou cinq mille euros par an,

c'est déjà beaucoup. Voilà. Donc l'intérêt de l'opération était dans le collectif pour permettre à des 'petits agriculteurs', entre guillemets, de pouvoir faire un tel projet."

[cxcii] "[La société] nous reverse un loyer. Mais comme on est actionnaires, la société nous appartient à nous, à la fin, s'il reste du résultat, l'argent nous reviendra. Donc en fait, on va toucher l'intégralité de la revente d'électricité, ou sous forme de loyer ou sous forme de dividendes. On débite des charges de fonctionnement de la société."

[cxciii] "On avait ce pouvoir, aussi, pour [dire à Tenesol] : 'bon, les gars, vous avez le toit à faire, vous avez un gros projet, c'est quand même 36 millions d'euros pour vous, c'est quand même de l'argent...' Et, voilà, ça leur permettait un peu de mettre la main à la pâte. On les tenait un peu, quoi."

[cxciv] "Et là, ce qu'on leur disait [aux banquiers], c'est que c'était comme si on avait la somme de plusieurs projets, mais on offre d'avantage de garanties qu'un projet individuel, dans le sens qu'on mutualise. Et quand on mutualise, on sécurise une bonne maintenance. Ca aussi, ça n'a pas été facile à leur faire comprendre."

[cxcv] "Donc, en octobre 2008, vous voyez, on commence à évoquer le dossier en disant, bien, on réfléchit à ça, puisqu'il y avait un questionnaire qui avait été envoyé à la Sicaseli pour voir comment techniquement le projet était monté."

[cxcvi] "Le monde agricole, vous savez, est un monde qui a des besoins pour entreposer, qui a des moyens qui sont contraignants, par rapport à leur activité, la variation de leur activité, et donc, arriver avec une solution qui leur permettait de construire un bâtiment auto-financé, c'était exceptionnel. "

[cxcvii] "[…] comme au Crédit Agricole, nous étions en avance sur les autres partenaires, on a eu l'occasion de réfléchir sur des procès pour pouvoir sécuriser les prises de décisions, on s'est posé les questions un peu avant les autres, en mettant en œuvre des outils pour pouvoir apprécier les risques techniques."

[cxcviii] "En gros, pour cette phase, on était sur du cinq fois, entre quatre et cinq fois ce que nous avions vu"

[cxcix] "Ce que l'on peut dire de façon générale sur ces opérations là, c'est que l'intérêt de la mutualisation c'est la division du risque; l'inconvénient de la mutualisation, c'est qu'il y a trop de monde, et qu'en cas de difficulté, de dysfonctionnement, c'est compliqué à régler."

[cc] "Et vu du porteur de projet, [le banquier] c'est une étape simple facile à mettre en œuvre, parce que tellement réfléchie et tellement portée depuis un certain temps qu'on a le sentiment que tous les sujets sont réglés. Vu du banquier, le sujet est un peu différent, puisque lui, il découvre un dossier qu'il va devoir auditionner. […] Et quand ce dossier est arrivé, il a posé des difficultés, vues du banquier, au-delà de ce que le porteur de projet avait pu imaginer."

[cci] "Donc, ce que je crois, c'est que les services back-offices des banques n'étaient pas préparés pour pouvoir gérer cette complexité, qui a été au-delà de ce qui avait pu être imaginé lorsqu'on a accepté, vendu ce dossier dans nos comités de crédit internes."

[ccii] "La deuxième difficulté, vue du banquier, ça a été la taille du projet en termes d'acceptabilité, donc de vision du risqué. Parce qu'on était sur des investissements de près de 40 millions d'euros, à l'époque, avec tous les porteurs de projets. On nous expliquait qu'il y avait eu un gros travail qui avait été fait en amont pour pouvoir écarter les exploitants agricoles qui n'avaient pas la capacité de baux à porter, ceux qui n'avaient pas de bons emplacements, ceux qui n'avaient pas les bonnes toitures, etc… Donc, on s'est dit, mettre plus de 30 millions sur la table, sur un risqué qui avait été pré-validé, ou qualifié, entre les porteurs de projets, et le banquier principal Crédit Agricole, pour savoir qui était capable de, même s'il y avait eu sur le papier cette pré-qualification, qui nous a été annoncée, on avait néanmoins nous, Crédit Agricole, un doute sur l'appréciation du risque. On s'est dit, la chose doit être regardée à deux fois."

[cciii] "[…] vue du banquier [la mutualisation] n'est pas une simplification, mais c'est une complication. C'est-à-dire, quand on dit "on a un bail", certes on a un document juridique, mais derrière, il y a autant de baux qu'il y a de bâtiments; ils doivent être contrôlés. On dit: on a une assurance; certes. Sauf qu'il y a autant d'assurances qu'il y a de sites à contrôler. Il y a donc, vu du banquier, une multiplication du travail qui peut être, certes, industrialisée, puisqu'il y a une

certaine répétition, mais c'est pas du copier-coller, puisque sur chaque situation, il y a une spécificité, et donc on est obligé de passer au scanner du contrôle, de la vérification, l'ensemble des documents et pièces et on ne peut pas dire: 'on a fait un contrôle de pièces, et on suppose qu'elles sont bonnes sur tous les sites.' "

[cciv] "Et donc, nous n'aurons pas la capacité de tout prendre, il va nous falloir organiser un partage de risques. Et là, on a découvert une deuxième difficulté, c'est-à-dire que ce que nous, nous avions apprécié, dans le groupe Crédit Agricole, comme des montages possibles, posait plus de difficultés lorsque nous échangions avec d'autres partenaires bancaires qui n'étaient pas passés par l'expérience que nous avions eu, précédente, de pouvoir déjà nous servir du montage avec une vingtaine d'agriculteurs. Puisqu'ils découvraient, eux, des dossiers avec une centaine d'agriculteurs."

[ccv] "Donc, ce qui se faisait préalablement dans un partage à deux ou trois a dû être organisé dans un partage finalement à six. Et une relation à six, c'est plus compliqué, ça prend plus de temps qu'une relation à deux ou à trois. Donc la gestion des processus de décisions dans chacun des établissements a dû être coordonnée, et nous avons mis en place un comité de pilotage avec le client, avec le fournisseur, pour pouvoir expliquer ce qui se passait derrière les banquiers, pour pouvoir informer de l'état d'avancée du dossier, les difficultés ou les contraintes des uns ou des autres [...]"

[ccvi] "Et puis c'est pas facile entre eux [les banques], quoi. Le Crédit Agricole, c'est le Crédit Agricole, mais c'était pas le Crédit Agricole qui prêtait, là, c'était sa filiale Unifergie […] Quand on monte à Paris, que c'est Unifergie, que c'est une filiale, ils connaissent plus personne. C'est comme si vous étiez à la [Banque Populaire] ou n'importe où, hein."

[ccvii] "Donc ça a été beaucoup de réunions, beaucoup de bagarres. Et après, c'était pas gagné. Ils nous ont donné le feu vert, c'était le 14 juillet 2009. […] On a eu le déblocage des fonds un an après. Un an après, pourquoi? Parce que, parce que, un accord de principe et puis, les dossiers, là arrivent les avocats, et chacun veut mettre sa bille, chacun trouve son problème… Non, ça a été cocasse!"

[ccviii] "En fait, pour trouver les sous, les banques au départ ils ont mis… ils ont trainé longtemps, longtemps, longtemps. D'ailleurs c'était un peu aberrant, quoi. Ils trouvaient toujours un papier, un prétexte, quelque chose qui allait pas; ça retardait, ça retardait, mais nous on avait déjà lancé tout."

[ccix] "Donc, une fois qu'on a réussi à coordonner les décisions de crédit, la difficulté—le sujet n'était pas fini, parce qu'il a fallu ensuite coordonner l'écriture du contrat, qui a pris un certain temps, puisque là nous n'étions plus entre commerçants, mais c'était les juristes qui discutaient entre eux dans chaque établissement bancaire."

[ccx] "Il y a un pool bancaire qui s'est mis en place, etc… Ensuite, là où on est intervenus avec Tenesol, c'est qu'il fallait qu'on présente un contrat entre Tenesol et la Sicaseli, et aussi les contrats d'assurance, les contrats de maintenance, les validations des bureaux de contrôle… enfin, il y a tout un tas de choses à mettre. Et puis, évidemment, le contrat qu'on a fait signer à la Sicaseli ne convenait pas aux banquiers; il manquait des clauses. Donc il a fallu faire évoluer ce contrat. Et ça a été assez long, parce qu'il y a eu une passation de pouvoir entre Toulouse – Unifergie Toulouse – et à un moment donné le siège parisien, qui a voulu, ou qui a dû, ou qui devait, j'en sais rien, qui a voulu prendre le contrôle sur le projet, qui a un peu écarté les Toulousains. Et les mecs de Paris ont commencé à mettre leur nez là-dedans avec les juristes, les assurances, etc., les banquiers. Et du coup, ça a pris beaucoup de temps."

[ccxi] "Je voudrais attirer votre attention sur la démarche exemplaire engagée par la coopérative dans ce projet ancré dans le territoire, porté par un groupe d'agriculteurs associés et impliqués financièrement pour investir ensemble dans les énergies renouvelables."

[ccxii] "Les travaux d'installation des centrales ont démarré en juillet 2009, sur la base d'un accord de financement du pool bancaire. Huit mois après le démarrage, les fonds ne sont toujours pas débloqués et les conditions financières de ce financement viennent tout juste d'être communiqués à la SAES. Celles-ci ne sont pas acceptables et sont même choquantes au regard des marchés financiers actuels et de la démarche territoriale engagée, profondément animée d'un esprit

mutualiste et coopératif. Le monde agricole, qui par ailleurs, traverse une crise profonde, ne peut comprendre qu'un tel projet territorial et collectif puisse être traité par ses partenaires financiers comme un projet photovoltaïque quelconque où seul semble compter le niveau de la marge commerciale obtenue."

[ccxiii] "Nous comprenons bien que ce projet, porté par la SAES, est l'aboutissement d'un engagement fort et long de votre Groupe auprès de ses adhérents, pour répondre à leurs attentes nouvelles, et nous vous en félicitons.

Cependant, comme vous l'indiquez ce projet est lourd et complexe – il concerne 110 agriculteurs, 220 bâtiments pour environ 60 000 m^2 de panneaux et une puissance installée de 7 MWc, et pour un coût global de 33.5 M€.

Ainsi, compte tenu de son importance, cet investissement a nécessité l'intervention d'un pool bancaire autour de notre Caisse Régionale et d'Unifergie, difficile à constituer, générant des délais et de longues discussions, desquelles nous nous employons énergiquement à sortir rapidement pour finaliser cette opération.

Nous vous précisons que les conditions vers lesquelles nous nous orientons (un peu plus de 5%) correspondent légitimement à ce type de projet très complexe, de par sa taille (220 toits), son montant de fonds à lever (27,5 M€ au dernier point), et du nombre d'intervenants (6 banquiers) ayant chacun, leurs propres contraintes tant juridiques que financières.

Les travaux d'installations des centrales sont aujourd'hui bien avancés, et nous vous engageons à trouver rapidement un accord avec l'ensemble des partenaires financiers, qui pourraient, pour certains d'entre eux, renoncer à l'accompagnement de ce projet."

[ccxiv] "On a découvert un monde qui nous était un petit peu étranger. Voilà, où la complexité administrative, où l'éloignement du monde réel, voilà, je le dirais comme ça, a des conséquences sur leurs postures, réactions de pensées, tout à fait… On l'aurait jamais pensé. Des gens qui se réassurent à chaque fois, qui nous font faire des audits pour des choses qui nous paraissaient évidentes…"

Conclusion

> "Once more 'round the Sun we go, again"
> Mastodon—*Once More 'Round the Sun*

In retrospect

Upon concluding this dissertation, it is interesting to take a look back at its original motivations and to contrast them with the final result. As outlined in Chapter 1, the originality of the research I presented here partly lied in its unfolding "*in medias res*". It developed as its object – namely, the emergence of grid-connected photovoltaics in France as driven by feed-in tariffs – evolved, shifted and was contested. It is therefore not surprising that research objectives and approach evolved along the way so as to better grasp an object in flux. Initially, this dissertation was intended to study the technological and territorial dimensions of the development of solar power in France, in the context of the objectives set by the *Grenelle de l'environnement* and supported by feed-in tariffs and calls for tender policies that were assumed to be stable. In other words, the focus was meant to be on the deployment of an innovation in the energy sector, and in particular on the drivers of technological change beyond policy support.

However, it soon appeared that, in this specific case, it made little sense to consider the emergence of photovoltaic technologies without questioning the markets on which they deployed and the policies that sustained them. Photovoltaics may be research-intensive technologies, but the photovoltaic research community is in fact fairly structured and the R&D aspects of photovoltaics are relatively stabilised. In strictly technological terms, photovoltaic research has been only marginally affected by the recent evolutions in the sector. It turned out that the puzzling changes and innovations in the photovoltaic sector were those driven by the policy-supported emergence of new markets for photovoltaics. These intertwined technology, markets and politics to such an extent that it became difficult to precisely delineate the three.

The brutal reconsideration of French photovoltaic support that occurred in late 2010 and the chaos that ensued only confirmed that there was something peculiar in the articulation of markets, politics and technological change at play in FIT-driven photovoltaic markets. This episode did not only emphasise the policy-dependence of the emerging French photovoltaic sector and market; it also revealed the political tensions at play in all their drama. It addition, it seemed to point to specificities of photovoltaic technologies: those had "reacted" to policy support in a very different manner than other renewable energy technology and proliferated at an unprecedented pace, suggesting there was something worth investigating in the very characteristics of photovoltaic technologies. This justified a focus on feed-in tariffs *for* PV-generated electricity as distinct from feed-in tariffs for other renewable energy technologies such as wind power, so as to explore the interactions of a specific policy device with the technologies it targeted.

A study of FIT-photovoltaics *agencements*

My focus thus shifted on feed-in tariffs as devices that drove and articulated the deployment of photovoltaics as a set of emerging renewable energy technologies, as a market, and as a political issue. Feed-in tariffs, in their very logic, aim to induce and accelerate technological change by fostering regulated markets. This dissertation thus constituted an attempt to grasp the emergence of a specific technology through the analysis of the creation of policy-dependent markets.

The core objective of this dissertation can be summarised as **the exploration of the *agencement* of feed-in tariffs for PV-generated electricity and of their effects on photovoltaic technologies, markets and politics**. From there, this dissertation has strived to describe feed-in tariffs not simply in what they do as market instruments calibrated to achieve specific policy objectives, but in **how they assemble heterogeneous elements in sometimes unexpected ways and trigger actions that they cannot always contain**.

In the **first two chapters**, I have deployed a series of ANT concepts related to technologies, matters of concerns and markets to propose a description of photovoltaic technologies and of feed-in tariff schemes and of their combination. In large part, the originality of photovoltaics stems from the modularity of photovoltaic technologies, that is to say from their ability to be assembled in very diverse ways and at different scales while performing the same core function of generating electricity from sunlight. Indeed, their modularity implies that photovoltaic technologies function both as silent interfaces performing a stabilised function *and* as flexible technological arrangements that can be assembled in many ways. I have shown that feed-in tariffs act on these two aspects of photovoltaic technologies, which I suggest can account for their heightened effectiveness in sparking the deployment of photovoltaics.

That is also why the concept of *agencement* proved useful in describing the emergence of photovoltaics as driven by feed-in tariffs. *Agencements* are heterogeneous combinations of people, things and discourses that are defined by their ability to trigger and structure action. From an ANT perspective, action is understood as always distributed and overflowing: it is defined as the setting into motion of chains of partially unpredictable mediators, rather than as the result of clearly sourced intentions. While they provide frames and structures for action to unfold, *agencements* also spark unexpected, unpredictable courses of action: they deploy along lines of stratification, which stabilise and incorporate novelty into existing frames, and lines of actualisation, which trigger innovation and inventiveness. On the one hand, feed-in tariffs for PV-generated electricity contribute to the stabilisation and pacification, or “cooling down” (Muniesa, 2010) of photovoltaic systems as interfaces: they disentangle photovoltaic electricity from the actual system that generates it and frame it as a tradable good that fits within the existing electricity system. On the other hand, they are designed to accelerate innovation, learning-by-doing and cost reductions; to this end, they activate photovoltaic technologies as flexible, customizable arrangements and equip new forms of agencies in the electricity sector.

Seen in this light, the function of feed-in tariffs is to activate and to frame the development and the exploitation of grid-connected photovoltaics as sources of renewable energy. Nonetheless, they are also policy devices, and their role is delimited by the political objectives that justify them. Their effects thus need to be controlled by policy-makers in order for feed-in tariffs to retain their political legitimacy and acceptability, which itself has to be constructed and maintained. The three case studies explored in the remainder of the dissertation highlight the tensions at play in feed-in tariffs for PV-generated electricity. These can be traced at different resolutions, of which my three case studies provide examples.

Chapter 3 focused on the European career of feed-in tariffs. Spanning over two decades of renewable energy policy in the European Union, it related the constitution of feed-in tariffs for PV-generated electricity as specific political market *agencements* with the dual (and somewhat paradoxical) objective to incorporate electricity from renewable energy sources into electricity markets without distorting them, and to stimulate the development of renewable energy technologies and production so as to, ultimately, modify the electricity mix. It stressed the experimental character of the evolution of feed-in tariffs at the shifting interface between politics, markets and research, and gave account of their effects and of the management thereof.

Chapter 4 zoomed on the French case. In particular, it analysed the photovoltaic "boom" of the years 2008 to 2010 and its political consequences, which culminated in a moratorium on feed-in tariffs and a subsequent sectoral crisis. It focused on two dimensions of the emergence of photovoltaics: the minutiae and material design of feed-in schemes contrasted with the evolution of the objectives they were expected to help achieve, and the (mis-)management of their unintended effects. I have shown how French feed-in tariffs for PV-generated electricity sparked a market and, because they proved unable to contain the overflows of this market, turned into a political issue and led to the constitution of market actors into a more or less organised public. Interestingly, it was still feed-in tariffs (albeit re-designed) that were used tentatively to quell the crisis and to attempt to silence the emergent public.

Chapter 5 considered feed-in tariffs for PV-generated electricity at the scale of a mutualised and territorial project. It analysed the constitution of FIT-supported photovoltaics into an opportunity and, later, into a resource for a rural area. In the case of the project developed by the cooperative *Fermes de Figeac,* feed-in tariffs acted as incentives, as they were meant to; but they also served as a basis and a catalyst for organisational and territorial innovation. I have shown how the *Fermes de Figeac* structured their project around the security and profitability guaranteed by feed-in tariffs while relying on their flexibility and adaptability, as well as on the modularity of photovoltaic modules, to build up specific capacities and turn photovoltaic electricity into a collective, territorial resource. In that, they carried feed-in tariffs away, using them to trigger effects that went beyond the mere increase in installed photovoltaic capacity. However, though it contributed to the overflowing aggregation of projects that was labelled as a "speculative bubble" in the late 2000s, the project of the *Fermes de Figeac* did not subvert the intentions of the feed-in scheme. It forced the technologies, institutions, procedures and actors involved in the project to adapt to the requirements of both feed-in tariffs and mutualisation. In so doing, the project triggered effects that had been unintended in the initial design of FITs, but it did not contest or subvert the framing provided by FIT market *agencements*. The *Fermes de Figeac* made the most of the potential of feed-in tariffs and photovoltaics to equip themselves as market and to an extent political actors (in that they acquired legitimacy and strength as players in the sector of territorial renewable energy), thereby taking feed-in tariffs forward. Contrary to photovoltaic projects motivated by financial gains only, the strong territorial rooting that structured the projects limited the risks of proliferation, making it less "threatening" from the point of view of national politics.

Gathering conclusions

These three case studies combined with the relational analysis of the modularity of photovoltaic technologies and of feed-in tariffs *agencements* shed light on the various ways in which feed-in tariffs for PV-generated electricity set in motion and gather people, things and institutions. As a result of this ANT take on photovoltaic technologies and on the devices that drive their development, this dissertation provided an alternative account of the FIT-driven emergence of photovoltaics. In this conclusion, I would like to stress four ways in which such an approach can complement existing research on renewable energy development and on the policies and market instruments that support it.

Registering the unintended effects of photovoltaic policies

First, from an empirical perspective, this dissertation suggests that sociology can contribute in documenting and assessing the effects of market support instruments. By focusing on the distributed, uncertain and overflowing character of the actions triggered by feed-in tariffs for PV-generated electricity, I have been able to consider some impacts of photovoltaic support that have not necessarily been registered by extant policy assessments. For instance, the analysis grids on which European or French institutions rely for assessing renewable energy policy did not seem to have registered projects such as that of *Fermes de Figeac*, in which feed-in tariffs for PV-generated electricity have served as a basis for building up capacity in the sector of cooperative renewable energy and as a device for territorial development.

On the contrary, the ANT approach adopted in this dissertation is equipped to record these unexpected consequences of feed-in tariffs because it focuses in what feed-in tariffs and photovoltaic technologies *make happen* rather than on the assessment of their performance with regards to what they were intended to do. This focus on events makes it possible to analyse cases in which feed-in tariffs were taken beyond their original objective (such as the *Fermes de Figeac* project), but also to document instances of overflowing (such as the moratorium and *consultation* analysed in Chapter 4) and to give account of the situations in which instruments go off-track.

Highlighting the active role of photovoltaic technologies

Attention to material settings and devices is a distinctive feature of ANT approaches and, throughout this dissertation, I have stressed the active role played by technologies and material devices. One of the core issues addressed in this dissertation is the interaction between feed-in tariffs as market *agencements* and photovoltaic technologies. Photovoltaic technologies are "fluid" (De Laët & Mol, 2000) insofar as they can be enacted in various configurations and still perform their function. But fluidity does not fully convey their specificities, which is why I have chosen to define photovoltaic technologies as modular. Indeed, photovoltaic modules can be assembled in installations of various scales and sizes: the amount of electricity an installation generates can be multiplied simply by adding modules. Modularity implies that photovoltaic technologies perform a stable function but have a potential for reconfiguration, adaptation to various environment and amplification – and hence for proliferation. I have argued that this could account in large part for the specificities of the FIT- driven deployment of photovoltaics as opposed to other sources of renewable energy. Owing in large part to the qualities of photovoltaic technologies, feed-in tariffs for PV-generated electricity do not have the same effects than feed-in tariffs for wind power, and they raise different types of issues.

I have then analysed how these technologies, along with the actors that contribute to their design and development, are equipped with economic and political qualities. Feed-in tariffs are designed to direct the activities of citizens and market actors towards photovoltaics, but they are also have direct effects on photovoltaic technologies, of which they at the same time stabilise certain characteristics (e.g. their ability to produce electricity tradable on the grid) and activate others (e.g. their flexibility, their potential for cost reduction, etc.). The outlet created by the rise of FIT-driven photovoltaic markets in Europe thus contributed to the massive expansion of photovoltaic cells production in China and to the dramatic – and unanticipated – cost reductions that followed.

Feed-in tariffs encourage forms of economic and political participation that is mediated through the installation of photovoltaic systems. However, their effects cannot be entirely anticipated or controlled. For instance, the case studies in this dissertation show that the FIT-driven deployment of photovoltaics can become politically disruptive (as explored in Chapter 4) or can serve to build up political competencies (as explored in Chapter 5). Seen in this light, photovoltaic technologies associated with feed-in tariffs can be said to enact a form of material participation (Marres, 2012).

An alternative account of feed-in tariffs for PV-generated electricity

This approach thus led to an alternative account of the functioning and effects of feed-in tariffs for PV-generated electricity. Prevalent approaches to feed-in tariffs or renewable energy support instruments more generally tend to consider them as market instruments that are set up and regulated by policy means. Feed-in tariffs are then usually analysed in either one or the other of these two aspects: some studies assess their characteristics, effectiveness and efficiency as economic instruments (e.g. Ménanteau et al., 2003; Couture & Gagnon, 2010; Schmalensee, 2012), focusing on their market effects, while others are interested in their politics, i.e. in how they were adopted and in the policy objectives they are supposed to meet (e.g. Lauber & Mez, 2004; Hoppmann et al., 2014; Marcy, 2011).

On the contrary, the ANT perspective adopted in this dissertation does not distinguish *a priori* the functioning of feed-in tariffs for PV-generated electricity from their politics. It produces an account of feed-in tariffs for PV-generated electricity as dynamic *agencements* that have unintended effects because they trigger activities, as opposed to instrumental "means to an end". They appear to oscillate between situations of relatively controlled experimentation and moments of overflowing and crisis, but at no point in the cases studied in this dissertation can they be reduced to an instrumental, determined function. By providing incentives for activities around photovoltaics, feed-in tariffs for photovoltaics have given rise to a large number and variety of projects, from that of *Fermes de Figeac* regarded as "exemplar" (Interview 22) to opportunistic and speculative investments. They have thus triggered evolutions in photovoltaic technologies (that find a new outlet of an unprecedented scale) and provoked the emergence of new and diverse kinds of market and in some instances political actors (photovoltaic developers, representatives of the sector, organisations such as *Fermes de Figeac*, etc…).

Therefore, if feed-in tariffs for PV-generated electricity appear so complicated to steer, it could be because their good functioning requires work of economic *and* political construction. The near impossibility to base feed-in tariffs on actual and reliable data on the evolution of technological costs is sometimes attributed to information asymmetries and/or regulatory capture (Commission of the European Communities, 1999; Lesser & Su, 2008). Such a perspective seems to assume that there is a stable collective of actors influencing these costs, and that information could thus be accessed, were it possible to gather this collective. On the contrary, this dissertation suggests that there is no such stable collective, since the dynamic effects of feed-in tariffs transform it by making new actors enter the sector. Since this collective is now constantly evolving and not structured, obtaining an evaluation of the "cost" of photovoltaics requires a thorough work of political construction. The outcome of the *concertation* in France and the failure of the *Syndicat des Energies Renouvelables* (SER) to establish its legitimacy as a reliable interlocutor for public authorities during the photovoltaic "boom" and the difficulties it encountered in formulating estimations of the costs of photovoltaic projects (Interview 16) can only suggest the difficulty of this work.

Investigating the regulation of a policy-dependent market

I have thus shown that the design of feed-in tariffs for PV-generated electricity as market *agencements* requires work of political articulation and collective valuation. This directly leads to a fourth issue addressed in this dissertation, which is that of the definition of and distinction between "markets" and "politics". Despite the difficulty to define them, these two categories seem impossible to elude completely, especially as they appear frequently in the literature and discourses on renewable energy support.

Following Callon's definition of an experimental market (Callon, 2009), I have considered the distinction between the realm of politics and the realm of markets as a shifting, provisional outcome of the creation of photovoltaic markets, but this does not alter the relevance of the two terms, nor the difficulty in defining them in a substantial yet dynamic manner. This issue goes far beyond the reach of this dissertation, but, as it is focused on an emerging regulated market, the research presented here has suggested ways in which to address it.

Indeed, studying the development of a regulated market supported by political prices forces one to investigate processes of market-making and of policy-making that go hand-in-hand. The analysis of feed-in schemes as *agencements* shows the extent to which the two dimensions cannot be separated: photovoltaic markets are regulated markets that cannot function without political intervention while, on the other hand, the fulfilment of photovoltaic policy objectives has been partially delegated to market processes.

An advantage of the notion of *agencement* is that it directs attention toward action: the point is not to define "politics" or "markets" in a general way, but to identify what frames a specific action (or type of actions) as market (trans)action or as political action. As far as market *agencements* are concerned, I have relied on Michel Callon's definition (Callon, 2013): feed-in tariffs are market *agencements* insofar as they frame transactions of photovoltaic electricity involving monetary compensation. On the other hand, to qualify feed-in tariffs as political *agencement*s, I have drawn on Marres' work on the co-articulation of publics and issues (Marres, 2007) and on Barry's reflections on politics and the political (Barry, 2001, 2002). Feed-in schemes are political *agencements*, I have suggested, insofar as they translate a specific articulation of the deployment of photovoltaics as an issue and frame the space of negotiation, discussion and contestation of this issue. Political *agencements*, like market *agencements*, have to be made and negotiated – the analysis of their making and contestation is what chapter 4 focuses on – and can overflow, leading to the emergence of new publics and issues. In the case considered here, the *agencement* of market transactions and that of issue articulation appear closely intertwined, since the balance of power in transactions depends on the articulation of political objectives and legitimacies and, in turns, affect them. The case thus appears particularly suited to study the complex dynamics between agencing markets and agencing issues, though I have only drafted such an analysis here.

Feed-in tariffs for PV-generated electricity can be described as "economisation policies" (Linhardt & Muniesa, 2011) insofar as they aim to foster the creation of markets to which the fulfilment of political objectives regarding the electricity mix are delegated. To an extent, the entrustment of markets with the task to develop renewable energy has driven the emergence of instruments such as feed-in tariffs or tradable green certificates. The position of the European Commission in the late 1990s and early 2000s is clear on that matter: the correction of market failures and the integration of the European electricity market were considered as more reliable than politics. However, the political dimension of feed-in tariffs for PV-generated electricity cannot be considered as implicit only. FIT-supported market are *explicitly* policy-dependent because the calibration of feed-in tariffs – hence the sizing of the markets they support – necessarily involves a form of political *agencement.* Feed-in tariffs have indeed been criticized for their political character. Even the attempt of the French government at a depolitisation of the adjustment of feed-in tariffs after the moratorium resulted from a dramatically political event, from an affirmation of sovereignty, and from an explicitly asserted re-allocation of powers, risks and responsibilities.

The study of feed-in tariffs for PV-generated electricity then leads to more general considerations on regulated markets and the fixation of political tariffs. In such markets, the formulation of prices depends on a compromise on a "shared" valuation that is at least partly determined through a political process of issue articulation. To be acceptable, this valuation must not only be economically relevant, it needs to be fair.

The issue of the "fairness" of prices is often linked to the construction of the calculative formulas that serve to establish them (Caliskan & Callon, 2010, p. 18; Muniesa 2003; Guyer 2009). However, in the case of French feed-in tariffs for PV-generated electricity, feed-in rates were not obtained as the result of a calculative formula, but directly as the outcome of political arbitrages and power relations among concerned actors; there are now formulas that determine their evolutions and adjustments, but they largely depend on the initial price, which was an *ad hoc* value resulting from a political appreciation of the acceptable size of the FIT-supported photovoltaic market. In this case, in the end, prices are calculated, but these calculations rely on a political *agencement* that reflects the articulation of the issue and its public at a given point and that was then partially translated into a market *agencement* and a formula for the monitoring of prices.

This gives a new meaning to the phrase “policy-dependent market”: photovoltaic markets are policy-dependent not only to the extent that they would not have developed at such scale without policy support, but also insofar as their operation depends on the formulation of policy objectives and the articulation of political issues. Beyond the issue of administratively regulated markets, this dissertation thus contributes to the analysis of the processes of collective valuations that sometimes intervene in price calculation, by emphasising the fact that market *agencements* often are also political *agencements*.

Limits and perspectives

For several reasons, this dissertation provides only a partial account of the emergence of grid-connected photovoltaics in France and of the issues it has raised. Some of its limitations are direct consequences of the choice to study things in-the-making and to focus on an object in flux and on set of sites that cannot cover the whole spectrum of photovoltaic-related activities and issues.

First, this choice implied that the analysis had to finish “in medias res”. There is, in fact, no real “conclusion” to the story related in this dissertation: photovoltaics are still emerging, and their future evolution remains uncertain. This dissertation has documented the changes in the situation between 2008 and 2013, which in some respects have been significant. Photovoltaics in France can be said to have gained “substance” and actuality, and to have become an actual market and political issue, albeit a small, still marginal one. Feed-in tariffs, once praised as a silver bullet for triggering growth in renewable electricity generation, have been reconsidered in the light of their over-achievements. Still, given the time lag between actual events and data collection, consolidation and analysis, as well as the fact that any research work has to end somewhere, the most recent developments could not be analysed in any depths here. That is why I have not covered the uncertain fate of feed-in tariffs, which the European Commission no longer seems to favour, or the recent debates about the French energy transition, even though both would deserve in-depth analysis and would clearly be of relevance to the results presented here.

A second limitation of the study in almost real time stems from the difficulty to access information. As mentioned above, there is an inevitable lag in the publication of data on market and sector evolution, which was especially limiting since the photovoltaic sector has changed dramatically from a year to the next in the period considered. The rapid pace of photovoltaic development, along with the fact that (at least in France) instruments and expertise to register and monitor it were scaled up only recently, made it challenging to obtain fresh *and* reliable information. Besides, since photovoltaics are a strategic market and a burning issue that is not settled yet, actors could understandably be reluctant to give away information, especially in the context of tension and uncertainty that followed the moratorium.

Partly as a result of these limitations, this dissertation leaves several dimensions of the emergence of photovoltaics under-explored. Some of these have been signalled in the conclusions of the relevant chapters. For instance, I have not looked into the internal dynamics and politics of European institutions. It is likely that there have been differences in approaching renewable energy support not just among European institutions but also within these very institutions, and studying them would certainly broaden the understanding of the career of feed-in tariffs and clarify the way they have been related to the issue of market integration.

The dissertation also touches on the issues of photovoltaic entrepreneurship and project development and of territorial planning, in particular in Chapter 5. These two aspects, however, are addressed only superficially and from the perspective of a single and in many respects exceptional project. Both turned out to be difficult to analyse in depth within the scope of this dissertation, mainly because it took time to identify and gain access to relevant interlocutors, for the reasons outline above. The photovoltaic value chain is long, diverse and fragmented, and it remains difficult to obtain a reliable picture of the French photovoltaic sector. Photovoltaics-related activities and firms have boomed in the late 2000s, only to decrease just as fast after the moratorium: instability combined with diversity only heighten the difficulties in mapping the sector. This was indeed one of the problems that the *consultation* highlighted. The view is clearer now, and it might be easier to study the motivations and strategies of the actors of the sector, their views on how the evolution of feed-in tariffs affected them, and their take on the appreciation of risk.

For similar reasons, the territorial aspect of the deployment of photovoltaics was hard to approach in 2010-11: regional institutions were overall overwhelmed, and it was still early to have a clear view on the projects that had started in the late 2000s and to select case studies (for instance, the project of the *Fermes de Figeac* was launched in 2008 and not completed until 2011). Local action in renewable energy has however structured since then and networks of territorial renewable energy actors have emerged, making the issue easier to study now and suggesting potential for comparisons of territorial photovoltaic projects.

Last, this dissertation calls for a broadening of perspective along two main dimensions. First, it provides material for a comparison with other countries, other renewable energy policy instruments and other renewable energy sources. To what extent can the dynamics described here inform an analysis of the emergence of photovoltaics in other countries with feed-in tariffs? To which accounts does the notion of *agencement* lead when used to describe other instruments, such as TGCs or calls for bids? Can the perspective developed here be used to study the emergence of similarly policy-driven but technologically very different renewable energies?

Second, it would be very interesting to contrast the story related in this dissertation with a broader, longer-term perspective on French renewable energy policy. In this dissertation, I have chosen to focus on a very short moment of the development of a source of electricity that remains marginal in France. This zoom on a small part of French energy policy allowed for a level of detail in the analysis that would have been hard to achieve with a larger scope, but it might have artificially magnified the importance of the issues at hand, hence the necessity to put the results in perspective against a broader historical background. But this zoom might also shed light on current issues that may be hard to pinpoint in the bigger picture.

Glossary

Actant (introduced in Chapter 1, p. 51): any entity involved in action. ANT prefers the term "actant" to that of "actor" insofar as it can designate non-humans as well as humans. See also *Action*, *Agency*.

Action (introduced in Chapter 1, p. 51): From an ANT perspective, "action" can be defined broadly as the production of differences (Callon, 2008). It is relational and never fully predictable. See also *Agency*.

***Agencement* (socio-technical) (introduced in Chapter 2, pp. 79 ff)**: The term "agencement" was originally crafted by Deleuze & Guattari (1980) to revisit and specify Foucault's definition of *dispositifs*. In English, it has been translated as "arrangement" and "assemblage" to characterise carefully adjusted sets of heterogeneous components. In this dissertation, I refer to socio-technical *agencements* as defined in recent ANT studies, that is to say as "arrangements endowed with the capacity of acting in different ways, depending on their configuration" (Caliskan & Callon, 2010, p. 9). In particular, the notion of *agencement* considers agency and the adjustments of heterogeneous components as interdependent. As a result, *agencements* provide structure but can also trigger novelty: in Deleuze's words, they are traversed by "lines of stratification" that stabilise them and "lines of actualisation" that carry them away. *Agencements* thus constitute a theoretical device to investigate the making of distributed and heterogeneous agencies, as well as their dynamic evolution. See also *Agency, Dispositif*, *Market agencement.*

Agency (introduced in Chapter 1, pp. 51 ff): From an ANT perspective, the term "agency" denotes the capacity to act in a specific way. It can refer either to a specific active entity itself or to what enables it to act – to an extent, in ANT, the two are more or less equivalent since *actants* are primarily defined by the relations that constitute them as such. ANT conceives of agency as distributed among heterogeneous entities (humans, devices, statements, rules, cognitive equipment, etc.), meaning that one never acts alone. Agency then depends on material and cognitive equipment and on networks of partners and relationships. It can vary in scale and scope depending on the evolutions of these equipments and networks, and differences in equipment and size of the networks induce asymmetries. Last, since agency depends on a set of heterogeneous components and relations that have to be enrolled, put together and kept together, it involves displacements, translations and mediations which cannot be fully controlled. Depending on their equipment, agencies can be "calculative", "economic" or "political", meaning that they are able to calculate, to conduce economic action (e.g. market transactions) or political action (i.e. public contestation), respectively. See also *Actant, Action, Agencement, Mediation, Translation.*

Attachment (introduced in Chapter 2, p. 99): The term "attachment" was crafted to denote processes of "active conditioning so that something might arrive" (Gomart & Hennion, 1999). It implies a perspective on action that moves beyond the dichotomy between passive and active, control and letting-go to focus instead on the ties that make happen and set in motion. In other words, it stresses the degree of control that is necessary to achieve abandon, to let things happen. In French, the peculiar dynamic of "attachment" is expressed as "faire faire" (Latour, 2000). See also *Mediation.*

Black box (introduced in Chapter 1, p. 44): a stabilised object or statement that is no longer disputed or problematic and that can be displaced and referred independently from the work, procedures, people, things, inscriptions, etc. that were necessary to its constitution (Pinch, 1992).

Calculation (introduced in Chapter 2, pp. 85 ff): In the ANT approach to the study of markets, calculation refers to the assessments, both quantitative and qualitative, that make it possible to list and compare entities and are thereby at the heart of market transactions. According to Muniesa & Callon (2002), calculation involves three sets of material and conceptual operations: the delimitation of a space for comparison, the classification and qualification of entities within this space of comparison, and the extraction of a result that can then circulate outside the initial space of calculation. See also *Framing*, *Disentanglement/re-entanglement.*

Captation (introduced in Chapter 2, p. 99): a term coined by Cochoy (2007) to describe the strategies and devices deployed to influence, divert and manipulate fleeting and fluid collectives (e.g. citizens, electors, clients, consumers). It "is a matter of having a hold over something that one does not, or rather not yet completely control" (Cochoy, 2007, p. 205).

Controversies (introduced in Chapter 1, p. 45): STS focus on controversies as moments during which the ramifications of a given problem are made visible, debated and ordered. The study of controversies as carried out in STS considers the articulation of the problem and the organisation of the group relevant to address it as co-produced in a single movement (Callon, Lascoumes & Barthe, 2001; Callon, 2006). See also *Hybrid forums, Issues, Matters of concern, Public.*

Disentanglement/re-entanglement (introduced in Chapter 2, p. 87): Disentanglement and re-entanglement are crucial operations in the framing and exchange of economic goods. Disentanglement, on the one hand, turns goods into stabilised and standardised commodities that can circulate from hands to hand by alienating them from their producers, previous owners, context, etc (Callon, 1998, 2005; Thomas, 1991). Re-entanglement, on the other hand, is what permits the re-appropriation of a good by its purchaser: it refers to the creation of new ties that incorporate a good into the world of its buyer and that are necessary to the achievement of the transaction (Callon, 2005). See also *Calculation, Framing, Market agencement.*

***Dispositif* (introduced in Chapter 1, p. 55 and Chapter 2, pp. 73 ff):** The notion of "*dispositif*" comes from the work of Michel Foucault, where it refers to networks of heterogeneous elements, both discursive and non-discursive, that have a strategic dimension and result from a combination of power and knowledge (Foucault, 1994; Agamben, 2007; Callon, 2013). *Dispositifs* have a dynamic dimension: they organise, govern and maintain specific power relations, but they also hold a potential for reconfiguration, creation and innovation. The notion is useful to account for the interplay of knowledge and materialities in government or market devices, for instance, and to pay attention to the effects and reconfiguration of such devices. Later, studying methadone, Gomart has used the term to refer to the specific configurations that "make/let happen" i.e. to the experimental settings that are designed to produce effects that perform methadone (Gomart, 2002). See also *Agencement, Multiplicity.*

Experiment (Chapter 2, p. 107 and in footnote 69, p. 98): The notion of experiment has been widely studied in STS, and, it follows, conceptualised in a variety of ways. The study of scientific experiments has progressively extended to economics, democracy and institutions (Mitchell, 2005; Millo & Lezaun, 2006; Laurent, 2013; Muniesa & Callon, 2007; Marres, 2012). Experiments imply the delimitation of a site of experimentation, the manipulation of objects whose ontology is at stake, and the public demonstration of results that can circulate outside the site of experimentation in which they were produced (Muniesa & Callon, 2007; Millo & Lezaun, 2006; Laurent & Tironi, 2014).

In this dissertation, I mainly rely on Muniesa & Callon's approach to economic experiments; they define an experiment as "a crucible in which theories, discourses, practices, interests, and materials can be gathered and elaborated" (Muniesa & Callon, 2007, p. 184) and as an attempt "to solve a problem by organizing trials that lead to outcomes that are assessed and taken as a starting point for further actions". Economic experiments can take place *in vitro* (i.e. in confined, artificial laboratories) or *in vivo* (i.e. with no distinction between "inside" and "outside" the experiments).

From a different perspective, Marres (2012, pp. 84-89) has distinguished four approaches to public experiments: epistemic, discursive, ontological, and material. The use of the term "experimental" in this dissertation is closest to the last two, which stress the necessity of the involvement of human and non-human actors in public experiments as a means to introduce new entities in society. The material perspective on public experiments approaches public experiments as devices for participation and on the material settings that enable such participation.

Fluidity (of technologies) (introduced in Chapter 1, p. 57): The notion of "fluid technologies" was introduced by de Laet and Mol (2000) to describe technologies whose boundaries are "vague and moving, rather than being clear or fixed" (de Laet & Mol, 2000, p. 225). It serves to analyse technologies that can exist in various – but not any – configurations and be framed in different ways, and whose success partly stems from this capacity to have "a number of possible boundaries" (de Laet & Mol, 2000, p. 237). They developed the term to describe one technology in particular, the "Zimbabwe Bush Pump", of which several versions exist, and which can be (and has been) reconfigured and enacted in different way. See also *Modularity*.

Framing (introduced in Chapter 2, pp. 83 ff): In ANT studies of economics and markets, "framings" are the operations through which what is to be taken into account is distinguished from what is not to be taken into account, thereby creating the conditions for specific actions (Callon, 1998). They indeed "extricate the agents concerned from [their] network of interactions and push them onto a clearly demarcated 'stage' which has been specially prepared and fitted out" (Callon, 1998, p. 253). ANT has identified several framings that organise market transactions, in particular the framing of goods as passive and pacified objects, the framing of agencies as calculative, the framing of market encounters, and the framing of prices (Muniesa & Callon, 2007; Caliskan & Callon, 2010; Callon, 2013). Such framings are rare and expensive outcomes and, by definition, they produce externalities and exclusions (since they define an "exterior"); as a result, they can trigger overflowings. These result from a backlash of this constructed exteriority. They lead to the reconfigurations of previous framings by the inclusion of previously unaccounted effects, entities or relations. See also *Calculation, Disentanglement/re-entanglement, Market agencement, Overflowing.*

Hybrid forums (introduced in Chapter 1, p. 46): the heterogeneous gatherings that emerge in the context of techno-scientific controversies and in which affected groups, experts, politicians and officials collectively define the problems at stake and the ways of addressing them (Callon, Lascoumes & Barthe, 2001). The term characterises the articulation of a controversy and of the assembly of those concerned by it, as well as the resulting ordering of knowledge and expertise. See also *Controversies, Issues, Matters of concern, Public.*

Intermediary (introduced In Chapter 1, p. 54): a passive interface between a cause and an effect, as opposed to "mediator" (Latour, 1991). See also *Mediation.*

Issue (introduced in Chapter 1, p. 47; developed in Chapter 2, pp. 110 ff): The term "issue" refers to unexpected problems that cannot be accommodated by existing institutions. In that, it is close to the notions of "matters of concern" and "overflowings". Issues arise when unintended and/or previously unaccounted effects are brought up and dealt with. They are not already-there but need to be made visible and articulated, which goes along with the articulation of the group of those concerned by it (the "public") (Marres, 2005, 2007; Latour, 2007; Callon, 2007). See also *Controversies, Hybrid forums, Overflowing, Matter of concern, Public.*

Market *agencement* (introduced in Chapter 2, pp. 82 ff): a specific form of socio-technical *agencement* that shapes and makes possible specific forms of economic actions, namely market transactions involving monetary compensation. They organise the framings that underlie market transactions. Callon's proposal to replace the study of "markets" by the study of "market *agencements*" implies to shift the focus from aggregated markets to the organisation of bilateral market transactions (Callon, 2013). See also *Agencement*, *Calculation, Disentanglement/re-entanglement, Framing, Overflowing.*

Matter of concern (introduced in Chapter 1, p. 46): As opposed to stabilised, immutable "matters of fact", the term "matters of concern" refers to disputed, multiple entities that have not yet been stabilised and unified. A "matter of concern" is what is at stake in a controversy. Studying a "matter of concern" implies studying both the matter of controversy and the assembly concerned by it: they can only be distinguished once it has been stabilised into a matter of fact. See also *Controversies, Hybrid forums, Issue, Public.*

Mediation, mediator (introduced in Chapter 1, p. 54): The concept of "mediation" was introduced to stress the unpredictability and the overflows of action. Like "translation", it refers to the displacements that arise when relationships are formed and maintained. When "mediations" are involved, effects (or outputs) cannot be directly deduced from causes (or inputs). "Mediators" always do more than just carryi a cause to its effects; it follows that they contribute to action but not in a fully determined, predictable ways. As opposed to "intermediaries", they are active and can trigger unintended effects (Hennion, 1993; Latour, 1991, 1993, 1994a, 2005). See also *Agency, Intermediary, Relationality Translation.*

Modularity (introduced in Chapter 1, pp. 58 ff): I use the term "modularity" to characterise technologies that are composed of modules assembled together, such as photovoltaics. A module is a standardised unit that performs a stabilised function and can work independently or be combined to others in various and more or less complex structures. The term "modularity" thus points to two features of such technologies. First, it highlights their adaptability of modular technologies, which can be easily displaced and arranged in diverse manners while retaining the same function. Second, it points to the fact that modules can be combined and assembled together in potentially very large and complex structures, thereby amplifying the effects of the technology. See also *Fluidity.*

Multiplicity (introduced in Chapter 1, p. 55): the notion that different versions of an object can coexist and are enacted in different practices (Mol, 1999; Law, 2004). As opposed to "pluralism", multiplicity implies that there is not one reality to which one can have partial access and that alternative versions of objects are not mutually exclusive. In practice, it translates into an attention to the practices that enact or perform objects and to their effects instead of attempts to define essences and substances (Gomart, 2002). See also *Relationality*.

Overflowing (introduced in Chapter 2, p. 84): A consequence of framing, overflowing (or overflow) occurs when what had been excluded, left unaccounted, or ignored, turns out to disrupt current framings and leads to their reconfiguration. Economic externalities, such as pollution, are a good example of overflowings (Callon, 1998). From an ANT perspective, framings are considered to always trigger overflowings, that is to say consequences and effects that they cannot readily absorb. See also *Framing, Issue.*

Performativity (Chapter 2, pp. 81, 82, 102): the claim that any discourse acts on its object, which implies that both natural science and social science contribute to the enactment of the realities they describe. The study of performation is thus the study of the "adjustment of statements and their worlds" (Callon, 2007). In particular, performativity studies have looked at the role of economics and economic models in the making and performance of the economy, granting importance to statements and knowledge as much as materialities (MacKenzie et al., 2007; MacKenzie, 2003; Holm & Nielsen, 2007; Muniesa, 2005).

Political (introduced in Chapter 2, p. 112): For Barry (2001, 2002), the term "political" refers to "an index of the space of disagreement" (Barry, 2002, p. 270). What is political is what opens up new spaces of disagreement, what cannot be reduced to politics and absorbed by codified institutions and procedures. Latour has also proposed five definitions of the word "political" that can help shifting the focus on issues (Latour, 2007; cf. Annex 12). See also *Issues, Overflowing, Politics.*

Politics (introduced in Chapter 2, p. 111): The definition of politics remains an unresolved issue in STS: does it refer to institutions, practices, and methods, such as delibration, representation, government, etc., or to specific realms and effects, such as sovereignty, the management of public affairs, etc. (Linhard & Muniesa, 2011)? Barry (2001, 2002), use the term to refer to the technical practices, codified procedures, forms of knowledge and institutions whose purpose is to channel dissensus and controversies. In a more general sense, when not referring to Barry, I use the term "politics" to designate the practices that articulate problems into public issues by organising their consideration, discussion and management. See also *Issue, Political, Public.*

Problematisation (introduced in Chapter 1, p. 45 and Chapter 2, p. 108): The notion of "problematisation" has been used in STS in a sense close to that which Foucault gave it to study the operations through which the formulation of problems is elaborated along with the ways to address them (Debourdeau, 2011b). It is not limited to public issues, but applies to scientific and technical entities, human subjects, and the modalities of their representation. In its broad definition, problematisation refers to the articulation and formulations of problems related to the identity, definition and representation of things and beings (Laurent, 2013). Callon has thus defined problematisation as the "gradual process of fragmentation and division of issues that evolves into the joint formulation of a set of different problems which in a sense, at least partially, substitute for the initial issue" (Callon, 2009, p. 543). The link to "issues" emphasises the fact that the emergence and definition of entities and beings raises concerns, and that the process of problematisation includes both the formulation of problems and the organisation of the groups concerned by them (Callon, 2012). Laurent has suggested the term "problematisation sites" to refer to diversity of places and venues in which issues are gradually formulated into problems. See also *Hybrid forum, Issue, Matter of concern.*

Public (introduced in Chapter 1, p. 47; developed in Chapter 2, pp. 110 ff): The notion of "publics" as referred to in this dissertation derives from Dewey's definition of the public as "all those who are affected by the indirect consequences of transactions, to such an extent that it is deemed necessary to have these consequences systematically cared for" (Dewey, 2010 [1927]). Publics come into play when existing institutions are unable to deal with the unexpected consequences and unintended effects of previous actions. Relying on this definition, Marres has stressed the fact that the emergence and articulation of a public cannot be taken for granted since those "jointly affected" by an issue are likely to have diverging interests. The articulation of a public, it follows, is a risky process that involves the articulation of the issue at stake and its discussion. See also *Controversies, Hybrid forum, Issue, Matter of concern, Overflowing.*

Relationality (introduced in Chapter 1, p. 50): One specificity of actor-network theory is that it conceives of entities are defined through relations: entities are not considered as stable and isolated unities, but instead as associations whose configuration can vary and in which both human and non-human play a part. This translates into an attention to the making and transformations of entities (including objects, actors, interests, categories and hierarchies) and to their heterogeneity. In particular, as far as actants are concerned, it implies that their identity, their capacity to act and their interests are not considered as fixed but as outcomes of fluctuating relations. See also *Actant, Agency, Multiplicity.*

Symmetry (introduced in Chapter 1, p. 44): in STS, the methodological commitment to account for success and failure and for the constitution of true knowledge and of false knowledge in the same ways and in similar terms. This entails that truth, efficiency or profitability are considered as outcomes that cannot be used to explain the process from which they result.

Translation (introduced in Chapter 1, p. 53): Like "mediation", the term "translation" stresses the alterations and displacements of action. It refers to the often strategic displacements and adjustments that are necessary to interest and enrol others. Spokespersons and "obligatory passage points" arise by translating the interests, characteristics, etc. of others; but, since translations are never perfect, the resulting relationships can always be overturned (Callon, 1986). See also *Agency, Mediation.*

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Annex 1: List of interviews

Interview 1	24 March 2011	Firm (Construction sector)
Interview 2	25 March 2011	French environmental NGO
Interview 3	5 April 2011	French NGO
Interview 4	7 April 2011	French *Député*
Interview 5	19 April 2011	ADEME (regional branch)
Interview 6	12 May 2011	Representative of the photovoltaic sector
Interview 7	1st June 2011	R&D, Thin-film photovoltaics
Interview 8	4 July 2011	R&D
Interview 9	7 July 2011	R&D, Silicium photovoltaics
Interview 10	25 June 2012	Industry representative, Electricians
Interview 11	5 July 2012	French NGO/data collection
Interview 12	11 July 2012	Administration (DG Trésor)
Interview 13	23 July 2012	Administration (DGEC)
Interview 14	25 July 2012	International organisation
Interview 15	26 July 2012	Administration (DGEC)
Interview 16	17 August 2012	Representative of the photovoltaic sector
Interview 17	21 August 2012	Utility
Interview 18	23 August 2012	Representative of the photovoltaic sector
Interview 19	17 September 2012	Standardisation organism
Interview 20	4 October 2012	Sicaseli-Fermes de Figeac
Interview 21	8 October 2012	Renewable energy sector
Interview 22	9 October 2012	Regulation authority (CRE)
Interview 23	22 January 2013	Administration (*Région*)
Interview 24	23 January 2013	Legal consulting firm
Interview 25	29 January 2013	Grid operator
Interview 26	12 March 2013	Farmers (SAS-SAES project, one member of the Administrative board)
Interview 27	12 March 2013	Farmer (Sicaseli Administrative board, SAS SAES Administrative board)
Interview 28	12 March 2013	Farmer (Sicaseli Administrative board, SAS SAES Administrative board)
Interview 29	13 March 2013	Farmer (Sicaseli Administrative board, SAS SAES Administrative board)
Interview 30	14 March 2013	Farmer (SAS SAES Administrative board)
Interview 31	15 March 2013	Farmer (Sicaseli Administrative board, SAS SAES Administrative board)
Interview 32	15 March 2013	Farmer (President of Sicaseli and SAS SAES)
Interview 33	15 March 2013	Photovoltaic sector (ex-Tenesol)
Interview 34	11 April 2013	Bank
Interview 35	19 April 2013	Utility
Interview 36	19 April 2013	Photovoltaic sector (inverters)
Interview 37	9 May 2013	NGO
Interview 38	14 May 2013	NGO (individual photovoltaic system owners)
Interview 39	16 October 2013	R&D (economics)
Interview 40	October 2013	Sicaseli manager

Annex 2: A standard purchase agreement for a photovoltaic installation on a residential building

CONTRAT D'ACHAT DE L'ENERGIE ELECTRIQUE PRODUITE PAR LES INSTALLATIONS UTILISANT L'ENERGIE RADIATIVE DU SOLEIL ET BENEFICIANT DE L'OBLIGATION D'ACHAT D'ÉLECTRICITE (S10)

Le présent contrat se compose des conditions particulières et de leurs annexes, ainsi que des conditions générales (CG PHOTO2010V1).
La version de ce contrat numérisée par l'acheteur tient lieu de document contractuel officiel.

CONDITIONS PARTICULIERES (PHOTO2010V1)
Contrat n° **BTA9999999**

Entre
ELECTRICITE DE FRANCE, Société Anonyme au capital de 924 433 331 €, inscrite au registre du commerce et des sociétés sous le n° 552 081 317, et dont le siège social est situé à Paris (8ème),

dénommée ci-après « l'acheteur »,

et
M Yves contrat Bien Signé

domicilié à :

22, Près de chez lui

99999 Ma Ville

dénommé ci-après « le producteur »,

1 - DESCRIPTION DE L'INSTALLATION DE PRODUCTION

Adresse : **22, Près de chez lui,**
Code postal : **99999** Commune : **Ma Ville**

Puissance-crête totale installée : **3** kWc
Type d'installation : Fixe

2 - RACCORDEMENT AU RESEAU PUBLIC ET POINT DE LIVRAISON

Tension de livraison : 230/400 V
Selon le mode de regroupement des points de livraison décrit à l'article VI des conditions générales :
vente en TOTALITE

3 - TARIF D'ACHAT T ET COEFFICIENT R

Conformément à l'article VII.1 des conditions générales, la valeur annuelle du plafond d'énergie est de 4500 kWh
La date de la demande complète de raccordement au réseau public est le **12/06/210**
L'installation est située en métropole continentale.

A la date de prise d'effet du présent contrat et conformément aux dispositions de l'article VII.2 des conditions générales, le tarif d'achat de l'énergie produite dans la limite du plafond annuel défini ci-dessus est de :
58 c€/kWh hors TVA,
car l'installation est éligible à la prime d'intégration au bâti réservée à un bâtiment à usage principal d'habitation, d'enseignement ou de santé.
L'énergie produite au-dessus du plafond annuel défini ci-dessus est rémunérée à 5 c€/kWh hors TVA.

4 - INDEXATION ANNUELLE DU TARIF D'ACHAT T

Le tarif d'achat T et le tarif d'achat au-dessus du plafond annuel sont indexés annuellement par application du coefficient L défini à l'article VII.5 des conditions générales.
Les dernières valeurs définitives des indices connues au 1er novembre précédant la date d'effet du présent contrat sont :

$ICHTrev\text{-}TS_0 = 104.2$ $FM0ABE0000_0 = 145.1$

5 - IMPOTS ET TAXES

Le producteur déclare bénéficier de la franchise fixée par l'article 293 B du code général des impôts

L'acheteur :

Le producteur :
Svf.

6 - PERIODICITE DE FACTURATION

Conformément aux dispositions de l'article IX des conditions générales, cette périodicité est de tous les ans à partir de la date d'effet du présent contrat .

7 - DATE D'EFFET ET DUREE DU CONTRAT

Conformément aux dispositions de l'article XI des conditions générales, le présent contrat prend effet à la date de mise en service du raccordement de l'installation, soit le 01/07/2010, et arrive à échéance le 30/06/2030.

8 - SOUSCRIPTION D'UN CONTRAT DE FOURNITURE POUR LES AUXILIAIRES

Conformément à l'article VI des conditions générales :
Le producteur n'a pas souscrit de contrat de fourniture : la consommation maximale annuelle des auxiliaires de l'installation objet du présent contrat est de 65 kWh .

9 - DECLARATION SUR L'HONNEUR

Le producteur déclare avoir pris connaissance des conditions générales "PHOTO2010V1" jointes et en accepter toutes les dispositions.

Le producteur atteste sur l'honneur que les générateurs de l'installation objet du présent contrat n'ont jamais fonctionné dans un cadre commercial ou industriel, ou produit d'électricité à des fins d'autoconsommation ou dans le cadre d'un contrat d'obligation d'achat.

Le producteur atteste également que les équipements de production photovoltaïques ont fait l'objet d'une intégration au bâti, le cas échéant simplifiée, que son installation respecte l'intégralité des règles d'éligibilité définies à l'annexe 2 de l'arrêté du 12 janvier 2010 modifié[1].
Le producteur atteste qu'il dispose d'une attestation de l'installateur certifiant que les ouvrages exécutés pour incorporer l'installation photovoltaïque dans le bâtiment ont été conçus et réalisés de manière à satisfaire l'ensemble des exigences auxquelles ils sont soumis, notamment les règles de conception et de réalisation visées par les normes NF DTU, des règles professionnelles ou des évaluations techniques (avis technique, dossier technique d'application, agrément technique européen, appréciation technique expérimentale, Pass'Innovation, enquête de technique nouvelle), ou toutes autres règles équivalentes d'autres pays membres de l'Espace économique européen.
Le producteur atteste qu'il tient cette attestation ainsi que les justificatifs correspondants à la disposition du préfet.

Fait en deux exemplaires, à Lyon

L'ACHETEUR **Représenté par**	**LE PRODUCTEUR** (ou son mandataire) **Représenté par** (Nom, Prénom) 30/08/2010.
Date de signature	Date de signature Yves Contrat bien signé

[1] Pour aider les porteurs de projets à s'assurer que l'installation respecte les conditions d'intégration ou d'intégration simplifiée au bâti, des listes de produits éligibles établies par le comité d'évaluation de l'intégration au bâti sont disponibles sur le site Internet *http://www.ceiab-pv.fr*. Ce comité, composé d'experts de la sphère publique, est chargé d'examiner les systèmes photovoltaïques et de rendre des analyses sur leur compatibilité avec les critères techniques d'intégration ou d'intégration simplifiée au bâti

Annex 3: Evolution of feed-in tariffs for photovoltaic electricity in France, 2002-2010

Tariffs levels are expressed in eurocents/kWh.

2002		2003	2004	2005	2006	2006 (10/07)		2007	2008	2009	2010 (12/01)			2010 (31/08)		2010 (02/12)
Individual < 5kWc	15.25	14. 793	14. 529	14.125	13.84	Stan-dard	30	30.52	31.193	32.823	BIPV ≤ 250 kWc	Residential	58	≤3kWc	58	58
														≥3kWc	51	Ø
												Educational and Medical	58	≤3kWc	51	51
														≥3kWc	51	Ø
Professional and collective < 1000 kWc												Other buildings	50	≤3kWc	44	44
														≥3kWc	44	Ø
												Simplified BIPV	42	≤3kWc	37	37
														≥3kWc	37	Ø
Other < 150 kWc						BIPV	55	55.964	57.187	60.176	Other	≤ 250 kWc	31.4	≤3kWc	27.6	27.6
														≥3kWc	27.6	Ø
												≥ 250 kWc	31.4xC	27.6 xC		Ø
Fiscal credit																
Loi du 10 février 2000																
													Comité d'évaluation des produits photovoltaïques intégrés au bâti			
Arrêté du 13 mars 2002						Arrêté du 10 juillet 2006					Arrêté du 12 janvier 2010			Arrêté du 31 août 2010		
															Décret du 9 décembre 2010	

Annex 4: Evolution of feed-in tariffs for photovoltaic electricity in France, 2011-2013

Tariffs levels are expressed in eurocents/kWh.

		2011				2012				2013					
		10/03		10/07	01/10	01/01	01/04	01/07	01/10	01/01	01/02		01/04	01/07	01/10
BIPV	**T1**	Residential ≤ 9kWc	46	42.55	40.63	38.80	37.06	35.39	34.15	31.59	All buildings ≤ 9KWC	31.59*	30.77*	29.69*	29.10*
		Residential]9-36] kWc	40.25	37.23	35.55	33.95	42.42	30.96	29.88	27.64					
		Residential > 36 kWc	T5	T5	T5	T5	T5	T5	T5	T5	All buildings > 100 kW	T5	T5	T5	T5
	T2	Educational and medical ≤ 36 kWc	40.6	36.74	33.25	30.09	27.23	24.64	22.79	21.43					
		Educational and medical > 36 kWc	T5	T5	T5	T5	T5	T5	T5	T5					
	T3	Other ≤ 9 KWc	35.2	31.85	28.82	26.09	23.61	21.36	19.76	18.58					
		Other > 9 kWc	T5	T5	T5	T5	T5	T5	T5	T5					
Simplified BIPV	**T4**	≤ 36 kWc	30.35	27.46	24.85	22.49	20.35	18.42	19.34	18.17	18.17*		16.81*	15.21*	14.54*
		]36-100] kWc	28.83	26.09	23.61	21.37	19.34	17.50	18.37	17.27	17.27*		15.97*	14.45*	13.81*
		> 100 kWc	T5	T5	T5	T5	T5	T5	T5	T5	T5		T5	T5	T5
Other 0-12 MWc	**T5**	Non BIPV Residential, educational and medical BIPV > 36 kWc Other BIPV > 9 kWc Simplified BIPV > 100 kWc	12	11.68	11.38	11.08	10.79	10.51	8.40*	8.18*			7.96*	7.76*	7.55*
Loi du 10 février 2000															
Comité d'évaluation des produits photovoltaïques intégrés au bâti															
		Arrêté du 4 mars 2011									Arrêté du 7 janvier 2013 modifiant l'arrêté du 4 mars 2011				
											* Arrêté du 7 janvier 2013 portant majoration des tarifs				

Annex 5: List of participants in the *concertation* on photovoltaics

ADEME	Public organism
Air Liquide	Private firm (photovoltaic materials)
Assemblée des Chambres Françaises de Commerce et d'Industrie	Industry représentative
Assemblée des Départements de France	Local governments
Assemblée permanente des Chambres d'agriculture	Agricultural sector
Associations de l'Industrie Photovoltaïque Française (AIPF)	Industry representative (photovoltaic panels and systems manufacture)
Association des maires de France (AMF)	Local governments
Association des producteurs d'énergie solaire indépendants (APESI)	Photovoltaic power producers
Association des Régions de France	Local governments
Association Nationale des Régies de services publics et des Organismes constitués par les collectivités locales	Local governnments, grid operators
Enerplan - Association professionnelle de l'énergie solaire	Representative of the photovoltaic sector
BPCE	Bank
Caisse des Dépôts et Consignations (CDC)	Public bank
Centre Scientifique et Technique du Bâtiment (CSTB)	Expertise (construction sector)
Comité de Liaison des Energies Renouvelables (CLER)	NGO (Renewable energy)
Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA)	R&D
Commission de Régulation de l'Energie (CRE)	Public organism
Commission de affaires économiques de l'Assemblée Nationale	Parliament
Compagnie Nationale du Rhône	Private firm
Confédération de l'Artisanat et des Petits Entreprises du Bâtiments (CAPEB)	Industry representative (construction sector, photvoltaic installers)
Conseil Economique pour le Développement Durable (CEDD)	Public organism
Members of Parliament : Jean Dionis du Séjour, Michel Diefenbacher, Serge Poignant, Geneviève Fioraso	Parliament
Ecologie Sans Frontières	NGO (Environment)
EDF (direction ENR, direction optimisation Amont/Avall et Trading, direction Système Energétiques Insulaires)	Utility
EDF Energies Nouvelles (EDF-EN)	Private firm (Renewable energy)
EDF SA	Utility
Electricité réseau distribution de France (ERDF)	Grid operator
Eurazeo	Bank
Exosun	Private firm (photovoltaic manufacturer)
Fédération Française du Bâtiment (FFB)	Industry representative (construction sector)

Fédération nationale des collectivités concédantes et régies (FNCCR)	Local governments, grid operator
Fédération nationale des syndicats d'exploitants agricoles (FNSEA)	Agricultural sector
First Solar	Private firm (Photovoltaic manufacturer)
Fonroche Industrie	Private firm (Photovoltaic manufacturer)
France Nature Environnement (FNE)	NGO (Environment)
France territoire solaire (FTS)	Think Tank
GDF Suez	Utility
Gimélec	Industry representative (Electricians)
Groupement des Particuliers Producteurs d'Electricité Photovoltaïque (GPPEP)	Installations owners representative
Hespul	NGO (Photovoltaic)
Institut national de l'énergie solaire (INES)	R&D
Juwi EnR	Private firm (Project development)
MPO Energy	Private firm (manufacturer of PV system components)
Neoen	Private firm (Project development)
Photowatt	Private firm (Photovoltaic panels manufacturer)
Réseau de transport d'électricité (RTE)	Grid operator
SAFT	Private firm (Manufacturer of electrical components)
Saint Gobain	Private firm (manufacturer)
Schneider Electric	Private form (electrical components)
Solaire Direct	Private firm (manufacturer, project développer)
SER-Soler	Representative of the photovoltaic sector
Sunnco GC	Private firm (Photovoltaic systems manufacturer)
Syndicat des énergies renouvelables (SER)	Representative of the renewable energy sector
Syndicat des entreprises de génie électrique et climatique	Industry representative (installers)
Syndicat National des Installateurs Photovoltaïque (SYNAIP)	Industry representative (installers)
TCE Solar	Private firm (manufacturer)
Tecsol	Bureau d'études
Tenesol	Private firm (photovoltaic systems manufacturer, Installer)
Total	Private firm (energy)
Touche pas à mon panneau solaire (TPAMPS)	NGO (Photovoltaic)
Union fédérale des consommateurs – Que Choisir (UFC)	NGO (Consumers)
Union Française de l'Electricité (UFE)	Industry representative (Electricity sector)
Union Nationale des Entreprises Locales d'Electricité et de gaz	Industry representative (local utilities)
Véolia	Utility

Annex 6: List of legal documents pertaining to photovoltaic policy

Bills

Loi n° 2000-108 du 10 février 2000 relative à la modernisation et au développement du service public de l'électricité. NOR: ECOX980016L.

Loi n° 2005-781 du 13 juillet 2005 fixant les orientations de la politique énergétique, dite loi POPE. NOR: ECOX0400059L.

Loi n° 2009-967 du 3 août 2009 de programmation relative à la mise en oeuvre du Grenelle de l'environnement, dite loi Grenelle 1. NOR: DEVX0811607L.

Loi n° 2010-788 du 12 juillet 2010 portant engagement national pour l'environnement, dite loi Grenelle 2. NOR: DEVX0822225L.

Loi n° 2010-1488 du 7 décembre 2010 portant nouvelle organisation du marché de l'électricité. NOR: EFIX1007918L.

Regulatory texts

1. Relative to tariffs structure and levels

2000

Décret n° 2000-1196 du 6 décembre 2000 fixant par catégorie d'installations les limites de puissance des installations pouvant bénéficier de l'obligatin d'achat d'électricité. NOR: ECOI0000505D.

2001

Décret n° 2001-410 du 10 mai 2001 relatif aux conditions d'achat de l'électricité produite par des producteurs bénéficiant de l'obligation d'achat. NOR: ECOI0100190D.

2002

Arrêté du 13 mars 2002 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: ECOI0200002A.

Arrêté du 13 mars 2002 fixant les conditions d'achat de l'électricité produite par les installations de puissance inférieure ou égale à 36 kVA pouvant bénéficier de l'obligation d'achat. NOR: ECOI0100648A.

2006

Arrêté du 10 juillet 2006 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: INDI0607867A.

2010

Arrêté du 12 janvier 2010 portant abrogation de l'arrêté du 10 juillet 2006 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil telles que visées au 3o de l'article 2 du décret no 2000-1196 du 6 décembre 2000. NOR: DEVE1000820A.

Arrêté du 12 janvier 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR DEVE0930803A.

Arrêté du 15 janvier 2010 modifiant l'arrêté du 12 janvier 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil telles que visées au 3o de l'article 2 du décret no 2000-1196 du 6 décembre 2000. NOR: DEVE1001417A.

Arrêté du 16 mars 2010 fixant les conditions d'achats de certaines installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVE1006506A.

Arrêté du 16 mars 2010 relatif aux conditions d'achat de l'électricité produite par certaines installations utilisant l'énergie radiative du soleil. NOR: DEVE1006508A.

Circulaire du 1er juillet 2010 relative aux tarifs d'achat de l'électricité photovoltaïque prévus par l'arrêté du 12 janvier 2010 et aux procédures d'instruction des dossiers. NOR DEVE1016692C.

Arrêté du 31 août 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil telles que visées au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVE1022317A.

Détail des conditions tarifaires définies par l'arrêté du 31 août 2010 (note de l'administration).

Décret du 9 décembre 2010 suspendant l'obligation d'achat de l'électricité produite par certaines installations utilisant l'énergie radiative du soleil. NOR: DEVX1031847D.

2011

Décret n°2011-240 du 4 mars 2011 modifiant le décret n°2001-410 relatif aux conditions d'achat de l'électricité produite par des producteurs bénéficiant de l'obligation d'achat. NOR: EFIR1106455D.

Arrêté du 4 mars 2011 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVR1106450A.

Arrêté du 4 mars 2011 portant abrogation de l'arrêté du 31 août 2010 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil telles que visées au 3o de l'article 2 du décret no 2000-1196 du 6 décembre 2000. NOR: DEVR1106448A.

Arrêté du 28 décembre 2011 homologuant les coefficients SN et VN résultant de l'application de l'arrêté du 4 mars 2011 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVR1200782A.

Arrêté du 30 décembre 2011 pris pour l'application de l'article 200 quater du code général des impôts. NOR: EFIE1134721A.

2012

Décision n° 337528 du 12 avril 2012 du Conseil d'Etat annulant partiellement l'arrêté tarifaire du 12 janvier 2010.

Décision n°345912 du 25 juin 2012 du Conseil d'Etat annulant la circulaire du 1er juillet 2010 relative à l'arrêté tarifaire du 12 janvier 2010.

Arrêté du 29 juin 2012 modifiant l'arrêté du 28 décembre 2011 homologuant les coefficients SN et VN résultant de l'application de l'a rrêté du 4 mars 2011 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVR1227845A.

Arrêté du 21 décembre 2012 modifiant l'arrêté du 28 décembre 2011 homologuant les coefficients SN et VN résultant de l'application de l'arrêté du 4 mars 2011. NOR: DEVR1241312A.

2013

Arrêté du 7 janvier 2013 modifiant l'arrêté du 4 mars 2011 fixant les conditions d'achat de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVR1302613A.

Arrêté du 7 janvier 2013 portant majoration des tarifs de l'électricité produite par les installations utilisant l'énergie radiative du soleil tel que visé au 3° de l'article 2 du décret n° 2000-1196 du 6 décembre 2000. NOR: DEVR1302615A.

Arrêté du 10 avril 2013 modifiant l'arrêté du 28 décembre 2011 homologuant les coefficients SN et VN résultant de l'application de l'arrêté du 4 mars 2011. NOR: DEVR1309701A.

Arrêté du 6 juin 2013 modifiant l'arrêté du 28 décembre 2011 homologuant les coefficients SN et VN résultant de l'application de l'arrêté du 4 mars 2011. NOR: DEVR1314970A.

Décision n° 344021 du 28 juin 2013 du Conseil d'Etat annulant partiellement l'arrêté tarifaire du 31 août 2010.

Délibération du 28 mai 2013 portant décision relative aux tarifs d'utilisation d'un réseau public d'électricité dans le domaine de tension HTA ou BT pour la période du 1er août au 31 décembre 2013. NOR: CRER1330926V.

Arrêté du 17 octobre 2013 modifiant l'arrêté du 28 décembre 2011 homologuant les coefficients SN et VN résultant de l'application de l'arrêté du 4 mars 2011. NOR: DEVR1326299A.

2. Relative to the CSPE

2007

Arrêté du 28 août 2007 fixant les principes de calcul de la contribution mentionnée aux article 4 et 18 de la loi n°2000-108 du 10 février 2000 relative à la modernisation et au développement du service public de l'électricité. NOR: DEVE0757947A

2008

Arrêté du 17 juillet 2008 fixant les taux de réfaction mentionnés dans l'arrêté du 28 août 2007 fixant les principes de calcul de la contribution mentionnée aux articles 4 et 18 de la loi no 2000-108 du 10 février 2000 relative à la modernisation et au développement du service public de l'électricité. NOR: DEVE0817977A.

3. Relative to grid connexion and administrative procedures

2000

Décret n° 2000-877 du 7 septembre 2000 relatif à l'autorisation d'exploiter les installations de production d'électricité. NOR: ECOI0000375D.

Décret n°2000-1196 du 6 décembre 2000 fixant par catégorie d'installations les limites de puissance des installations pouvant bénéficier de l'obligation d'achat d'électricité. NOR: ECOI0000505D.

2001

Décret n°2001-410 du 10 mai 2001 relatif aux conditions d'achat de l'électricité produite par des producteurs bénéficiant de l'obligation d'achat. NOR: ECOI0100190D .

2003

Décret n° 2003-229 du 13 mars 2003 relatif aux prescriptions techniques générales de conception et de fonctionnement auxquelles doivent satisfaire les installations en vue de leur raccordement aux réseaux publics de distribution. NOR: INDI0301060D.

Arrêté du 17 mars 2003 relatif aux prescriptions techniques de conception et de fonctionnement pour le raccordement à un réseau public de distribution d'une installation de production d'énergie électrique. NOR: INDI0301278A.

2005

Décret du 07 septembre 2005 relatif à la rénovation des installations de production électrique sous obligation d'achat et modifiant le décret no 2001-410 du 10 mai 2001. NOR: INDI0505459D.

2008

Arrêté du 23 avril 2008 relatif aux prescriptions techniques de conception et de fonctionnement pour le raccordement à un réseau public de distribution d'électricité en basse tension ou en moyenne tension d'une installation de production d'énergie électrique. NOR: DEVE0808815A.

2009

Circulaire du 18 décembre 2009 relative au développement et au contrôle des centrales photovoltaïques au sol. NOR: DEVU0927927C.

Décret du 4 mars 2009 modifiant le décret n° 2001-410 du 10 mai 2001 relatif aux conditions d'achat de l'électricité produite par des producteurs bénéficiant de l'obligation d'achat. NOR: DEVE0903774D.

Décision ministérielle du 5 juin 2009 relative aux tarifs d'utilisation des réseaux publics de transport et de distribution d'électricité. NOR: DEVE0911965S.

Décret n° 2009-1414 du 19 novembre 2009 relatif aux procédures administratives applicables à certains ouvrages de production d'électricité. NOR: DEVU0901753D

2010

Arrêté du 15 février 2010 modifiant l'arrêté du 23 avril 2008 relatif aux prescriptions techniques de conception et de fonctionnement pour le raccordement à un réseau public de distribution d'électricité en basse tension ou en moyenne tension d'une installation de production d'énergie électrique. NOR: DEVE1004524A.

Décret n° 2010-301 du 22 mars 2010 modifiant le décret n° 72-1120 du 14 décembre 1972 relatif au contrôle et à l'attestation de la conformité des installations électriques intérieures aux règlements et normes de sécurité en vigueur. NOR: DEVE0927916D.

Décret du 17 mai 2010 modifiant le décret du 23 avril 2008 relatifs aux prescriptions techniques générales de conception et de fonctionnement pour le raccordement d'installations de production aux réseaux publics d'électricité. NOR: DEVE1004713D.

Délibération du 18 novembre 2010 portant décision sur les règles d'élaboration des procédures de traitement des demandes de raccordement aux réseaux publics de distribution d'électricité des installations de production d'électricité à partir de sources d'énergie renouvelable d'une puissance inférieure ou égale à 3 kVA. NOR: CREE1107141S.

2011

Arrêté du 14 juin 2011 définissant la diffusion de données locales sur les energies renouvelables, pris en application de l'article 88 de la loi no 2010-788 du 12 juillet 2010 portant engagement national pour l'environnement. NOR: DEVD1109597A

Décret n° 2011-1893 du 14 décembre 2011 modifiant le décret no 2000-877 du 7 septembre 2000 relatif à l'autorisation d'exploiter les installations de production d'électricité. NOR: EFIR1124315D

Décret n° 2011-2018 du 29 décembre 2011 portant réforme de l'enquête publique relative aux opérations susceptibles d'affecter l'environnement. NOR: DEVD1114607D.

Décret n° 2011-2019 du 29 décembre 2011 portant réforme des études d'impact des projets de travaux, d'ouvrages ou d'aménagements. NOR: DEVD1116968D

2012

Arrêté du 4 janvier 2012 pris en application de l'article 4 du décret no 2010-1022 du 31 août 2010 relatif aux dispositifs de comptage sur les réseaux publics d'électricité. NOR: INDR1134076A.

Décret n° 2012-38 du 10 janvier 2012 fixant le barème des indemnités dues en cas de dépassement des délais d'envoi de la convention de raccordement ou de réalisation du raccordement des installations de production d'électricité à partir de sources d'énergie renouvelabled'une puissance inférieure ou égale à trois kilovoltampères. NOR: INDR1123368D.

Décret n° 2012-533 du 20 avril 2012 relatif aux schémas régionaux de raccordement au réseau des énergies renouvelables, prévus par l'article L. 321-7 du code de l'énergie. NOR: INDR1209289D.

Délibération de la Commission de régulation de l'énergie du 24 mai 2012 portant application des règles tarifaires pour l'utilisation des réseaux publics d'électricité. NOR: CREE1225162S

Décision n° 330548 du Conseil d'Etat du 28 novembre 2012 annulant le TURPE 3.

2013

Délibération de la CRE du 25 avril 2013 portant décision sur les règles d'élaboration des procédures de traitement des demandes de raccordement aux réseaux publics de distribution d'électricité et le suivi de leur mise en œuvre. NOR: CREE1311515S.

Délibération du 29 mars 2013 portant proposition relative aux tarifs d'utilisation d'un réseau public d'électricité dans le domaine de tension HTA ou BT pour la période du 1er août 2009 au 31 juillet 2013. NOR: CRER1312494V.

Décision du 24 mai 2013 relative aux tarifs d'utilisation d'un réseau public d'électricité dans le domaine de tension HTA ou BT pour la période du 1er août 2009 au 31 juillet 2013. NOR: DEVR1312506S.

4. Relative to calls for tenders

2011

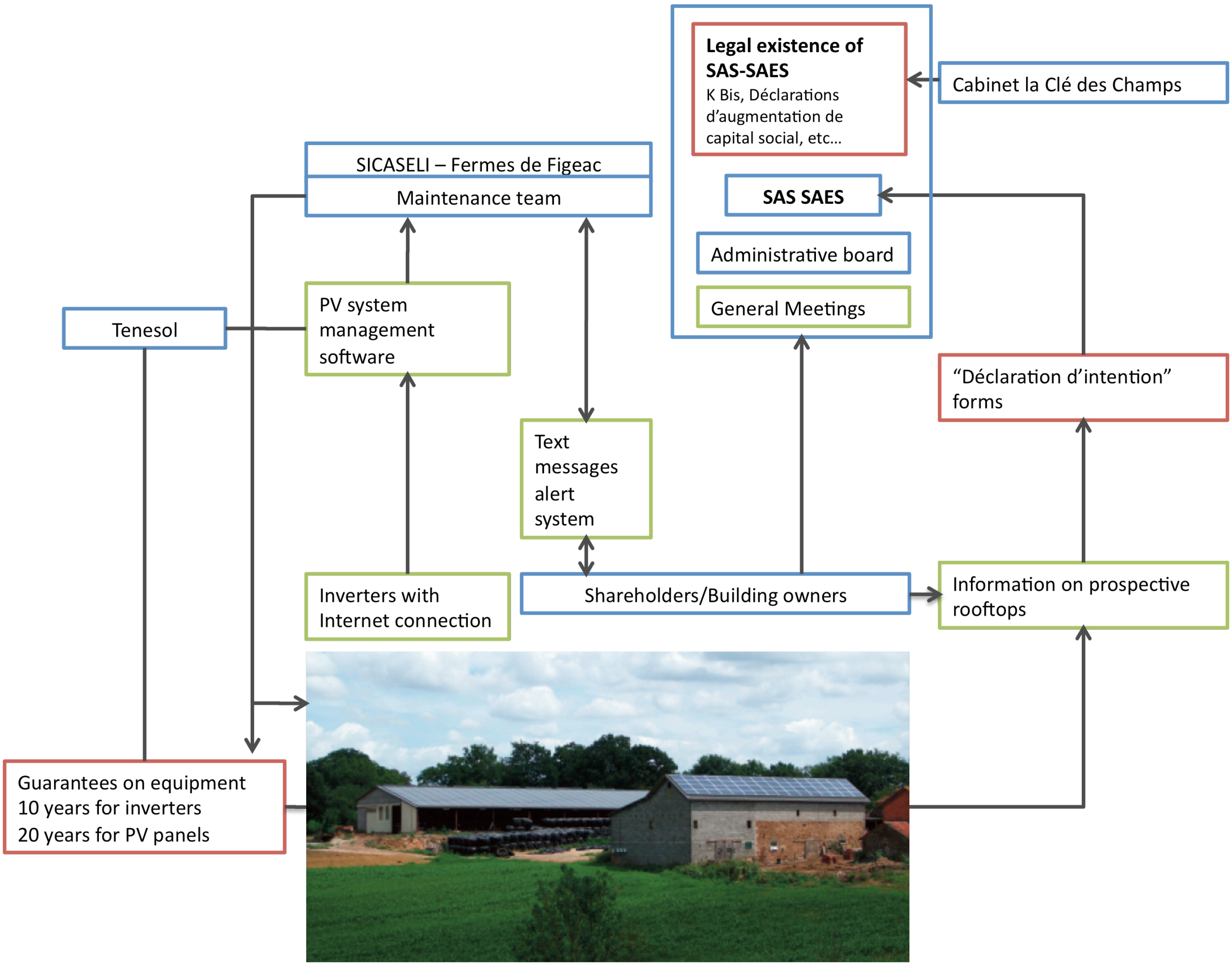
Arrêté du 14 juin 2011 autorisant la société Centrale photovoltaïque de Largentière à exploiter une installation de production d'électricité. NOR: DEVR1116551A.

Arrêté du 14 juin 2011 autorisant la SARL CEPE de la Salesse à exploiter une installation de production d'électricité. NOR: DEVR1116559A.

Arrêté du 14 juin 2011 autorisant le transfert de l'autorisation d'exploiter une installation de production d'électricité de la SAS Fonroche Investissements à la SASU Fonroche Serres.

Arrêté du 14 juin 2011 autorisant la société Seine et Aube Energie à exploiter une installation de production d'électricité.

Annex 7: Organisation of the *Fermes de Figeac* project and information transfers

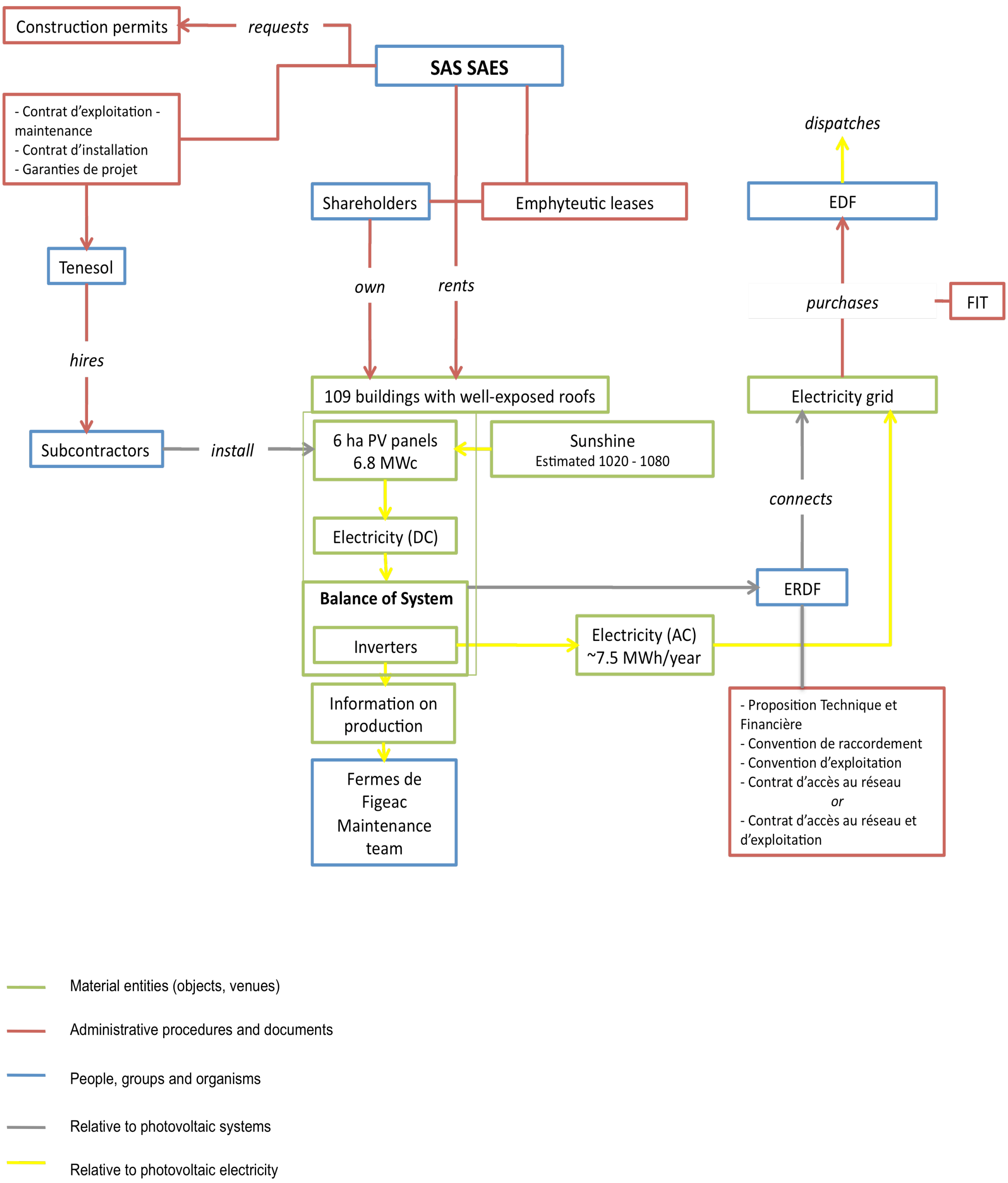


Material entities (objects, venues)

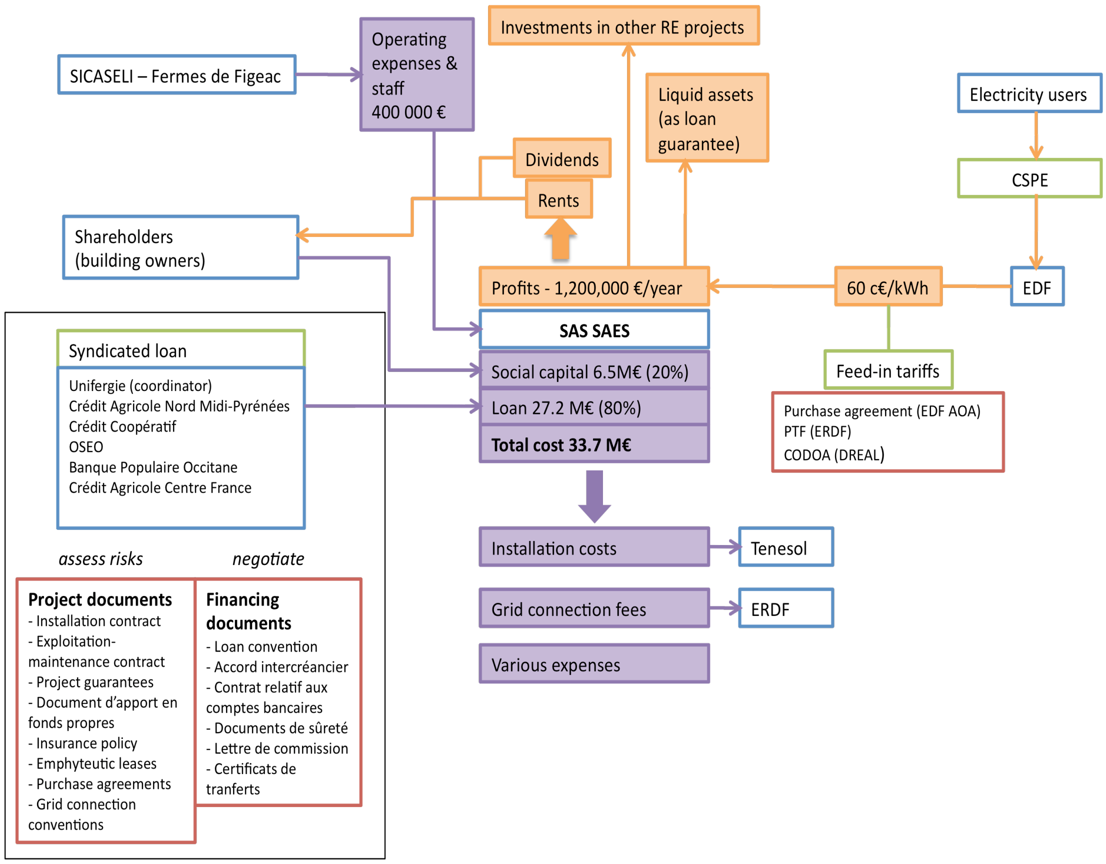
Administrative procedures and documents

People, groups and organisms

Annex 8: Material arrangement of the *Fermes de Figeac* project



Annex 9: Financial organisation of the *Fermes de Figeac* project



Material entities (objects, venues)

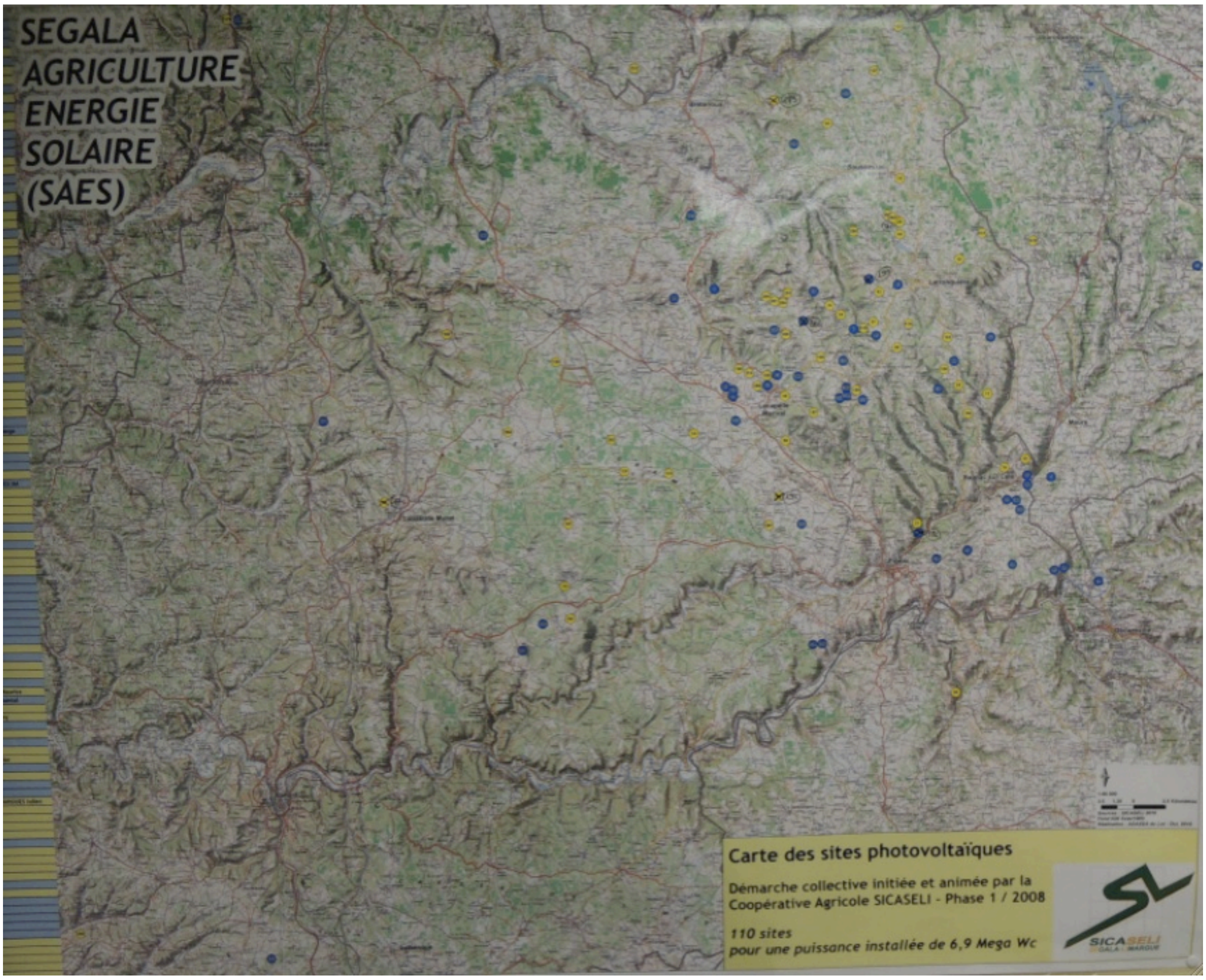
Administrative procedures and documents

People, groups and organisms

Profits

Payments

Annex 10: Map of the SAS SAES photovoltaic installations



Annex 11: The study of public policy instruments

Lascoumes and Le Galès's objective in proposing a program for the study of public policy instruments is to draw attention on an often overlooked dimension of political sociology, namely, the role of instrumentation in public policy change. They start from the observation that instruments are most of the time treated either as evidence, or as secondary issues in public policy analysis; the dominant approach to policy instruments, they say, follows a functionalist orientation (Lascoumes & Le Galès, 2007, p. 3).

On the contrary, they posit that instrumentation is a crucial aspect of public policy that should be studied in its own right for at least two reasons. First, instruments contribute to the organisation of relations between political society and civil society through the combination of technical and symbolic components. Their study can reveal the specific theorisations of the relationships between the governing and the governed that are at play in their operation. According to Lascoumes and Le Galès, a public policy instrument is indeed "a device that is **both technical and social**, that **organizes specific social relations** between the State and those it is addressed to, according to the representation and meanings it carries. It is a particular type of institution, a technical device with the generic purpose of **carrying a concrete concept of the politics/society relationship** and sustained by a **concept of regulation**" (Lascoumes & Le Galès, 2007, p. 4).

Second, they argue that instruments are never neutral: the produce specific effects independently of the initial objective that they were set to achieve. These effects have to be accounted for, especially since they can have a political dimension and affect power relations. This directs attention towards the history of instruments and of instrument choices, which can provide insight on public policy change. Every instrument, they write, "has a history, of which it remains the bearer, and [...] its properties are indissociable from the aims attributed to it. Similarly, because an instrument has a generic scope – that is, it is intended to apply to diverse sectoral problems, it will be mobilized by policies that are very different in their form and their basis" (Lascoumes & Le Galès, 2007, p. 6). Therefore, the historical dimension of instrumentation is crucial. Instruments have careers: they produce effect, are seized by new actors, mobilised for new purposes in different sectors, recycled, transformed, adapted…

Such an approach allows for the consideration of four aspects of public policy instruments: their historicity, their normative as well as cognitive content, the networks that they weave and that are structured by them as much as they structure them, and the effects that they produce (Lascoumes & Le Galès, 2005, p. 363-364).[143] It thus clearly seems informed by Foucault's work, and public policy instruments as defined by Lascoumes and Le Galès can be considered as specific forms of *dispositifs*.[144] They

[143] "[...] pour nous, l'approche en termes d'instrument inaugure une démarche de recherche, c'est-à-dire une focalisation sur une dimension qui permet d'envisager aussi bien l'historicité de l'instrument, que ses contenus cognitifs et normatifs, les réseaux d'acteurs qu'il tisse (qui l'enrichissent de leurs usages et de leurs critiques) et les effets qu'il produit"

[144] In French, Lascoumes et Le Galès use the term "dispositif" (translated as "device" in the English version) when defining of public policy instruments, without specifying whether they take it from Foucault or use it in a more generic way. They refer to Foucault later in the text,

comprise heterogeneous elements, both technical and symbolic the combination of which translates specific conceptions and articulations of power and knowledge; they organise action and structure power relationship; they are historical constructs that produce intended as well as unintended effects.

This perspective is helpful to disentangle PV support instruments as policy devices, that is as specific *dispositifs* that are designed and implemented through political processes. Approaches in terms of public policy instrumentation indeed provide insights on the techniques, details and practices of policy-making in both its mundane and sovereign dimensions (which often lack in alternative perspectives). They inform the case studies presented in this dissertation in several respects, especially the analysis of the evolution of feed-in tariffs (chapter 3) and that of the political struggles at stake in the elaboration of PV support instruments and in the management of their effects (chapter 4).

Nevertheless, on some aspects my approach to PV support also diverges from, or slightly modifies, that of Lascoumes & Le Galès. Indeed, I believe that an approach that would consider PV support as public policy instruments only would miss out on crucial characteristics of the emergence of photovoltaic for three main reasons.

First, the analysis of public policy instruments often assumes the politics of instruments to be implicit. The political dimension of instrumentation is then usually considered as operating 'under the radar', either because the recourse to instruments and devices was used to intentionally depoliticise an issue, or because their sedimentation into routines has made the politics of instruments invisible. In this light, the study of instrumentations contributes to making explicit the power relations that are at play within instruments and that would otherwise not be visible (see for instance Lorrain, 2005, p. 165-166). In some cases, instrumentation is indeed used as a means of depoliticisation and automation. Yet, I would argue that it does not necessarily operate on an implicit levels: instruments can also be a means to bring an issue into existence on the public scene, and their politics can at times be very explicit and visible (though this does not necessarily last). In the case of photovoltaic, the political dimension of support moves from visibility to invisibility as instruments evolve and change status, and whether their workings and the power relations they organise are explicit or implicit is in fact at stake in the analysis. The issue is thus not just to disentangle the politics behind PV support instruments, but also to understand how these instruments oscillate between dynamics of politicisation and depoliticisation. When and how do they contribute to the political articulation of photovoltaic as a public issue? When and how, on the contrary, are they used to depoliticise PV support?

A second and related limit of a public policy analysis perspective pertains to the materiality of instruments. For sure, studies of public instrumentation as a set of *dispositifs* constitute a first step towards the consideration of the materiality of instruments and policy-making, since they take into account both the social/symbolic and the technical dimensions of instruments. Yet, this attention to materiality is often limited to the technical aspects of instruments. Techniques and formulas are viewed as the outcomes of power struggles, or as the incorporation of specific conceptions of the relations between the governed and the governing; they are rarely considered as overtly

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mostly for his work on governmentality, and it is made clear that his perspective influences their approach (Lascoumes & Le Galès, 2005).

political, that is as having political effects of their own right. However, the materiality of instruments does not have to be merely technical; in some instances, it can be eminently political, because it contributes to making specific issues and dynamics visible (Barry, 2004), or because it directly affects power relations by framing/equipping new forms of agencies (Marres, 2012). In short, though they cannot be reduced to their material dimension, instruments have material components *and* produce material effects and *these* can be political too.

Last, quite naturally, the study of public policy instrumentation focuses exclusively on policy. This of course is not an intrinsic shortcoming: one could hardly blame public policy analysts for studying public policy. It is, however, a limit when it comes to analysing PV support. Feed-in tariffs (and other forms of PV support) indeed are policy instruments, since they are outcomes of policy-making processes and result from political struggles. But when considered in light of their mode of operation, feed-in tariffs are market devices: their aim is to foster the creation and development of specific markets by orienting the choices of economic actors and by framing photovoltaic technologies and photovoltaic electricity as economic products with specific characteristics. PV support has political effects, but it has economic/market effects as well, and to be fully understood it has to be grasped along both of these dimensions. Public policy analysis alone is not fully equipped to address this duality of PV support: it can account for the making and reforming of support instruments, but not for their mode of operation and their specific agency.

Annex 12: Latour's five definitions of the word "political"

In a reply to de Vries, Latour takes up and extends the perspective of "object-centred politics". Drawing on Noortje Mares reinterpretation of the works of Dewey and Lippman (Marres, 2005, 2007), he proposes a pragmatist turns that would start from issues to study their political trajectories. Here, "'political' is not an adjective that defines a profession, a sphere, an activity, a calling, a site, or a procedure, but it is what qualifies a *type of situation*" (Latour, 2007, p. 814). Politics, in this pragmatist perspective, is not an essence but something that moves, following, and revolving around, the evolution of matters of concern

If politics are not a predefined essence but move along with issues, and if issues have trajectories, then, there must be several ways in which something can be "political". An issue may change shape, be dealt with according to varying procedures and be accounted for in different manners while remaining "political" throughout. In an attempt to map out the trajectories of issues, Latour defines five types of political moments that can also serve to qualify the degree of turbulence or, on the opposite, sedimentation of a specific issue.

"Political-1" refers to issues are they are traditionally addressed by STS, that is as the "production of new associations between humans and non-humans" – typically an outcome of scientific practice and technological innovation. Such new associations are not necessarily explicitly political, in that they do not necessarily trigger mobilisation beyond the scientific realm, but they nonetheless entail a redefinition of the collective or, as Latour puts it, "the common world". At the other end of the spectrum, "political-5" is close to Foucault's definition of governmentality. It refers to the stabilised agents of political administration and management that silently embody – and maintain – a definition of the collective and of the power relations that shape it: "all those institutions [that] appear on the surface to be absolutely *apolitical*, and yet in their silent, ordinary, fully routinized ways they are perversely the most important aspects of what we mean by living together" (Latour, 2007, p. 817).

While these two definitions of the political refer to processes operating under the radar that STS have addressed extensively, the other three focus on what is visible and explicitly political. They stress the variety of processes and practices involved in the definition, articulation and management of issues.

"Political-2" points to emerging (or re-emerging) issues that existing institutions and groups are unsure how to address, because they lack equipment to do it and/or because these problems remain under-articulated. It corresponds to the situations studied by the pragmatists: those in which "an issue generates a concerned and unsettled public" and the need arises to deal with "consequences that entangle many unanticipated actors without […] any [developed] instruments to represent, follow, take care of, or anticipate those unexpected entanglements" (Latour, 2007, p. 816).

Latour then defines "political-3" as that which involves matters of sovereignty and even of "life and death". In his words, it corresponds to moments "when the machinery of government tries to turn the problem of the public into a clearly articulated question of common good and general will, and fails to do so" (Latour, 2007, p. 816). With "political-3", then, the definition and cohesion of the political collective, "the City", are at stake.

Last, "political-4" refers to issues that are stabilised enough "to be absorbed by the normal tradition of deliberative democracy" (Latour, 2007, p. 817). I corresponds to the management and administrations of public issues that are relatively well-defined: the range of concerned actors and their interests are identified, institutions and procedures have been established to channel disagreements and succeed in doing so, the terms of the debates are articulated and relatively stable. In other words, "political-4" points to situations where the public is no longer a prsoblem but a solution, making a form of rational deliberation possible. According to Latour, STS so far have tended to limit their investigation to this definition when dealing with politics and policy-making, and it is time they extended their scope to the rest of political action.

Table 9 Summary of the successive meanings of political through which a given issue might pass (Latour, 2007, p. 818)

Meaning of "political"	What is at stake in each meaning	Examples of movements that detected it
Political-1	New associations and cosmograms	STS
Political-2	Public and its problems	Dewey, pragmatism
Political-3	Sovereignty	Schmitt
Political-4	Deliberative assemblies	Habermas
Political-5	Governmentality	Foucault, feminism

This framework suggests that the evolution of issues goes through successive stages.[145] Even though Latour has stressed that the process is not linear (Latour, 2008), he speaks of "stages" in the "trajectory of issues", thereby implying that issues tend towards gradual stabilisation to eventually disappear from sight (political-5 has to be uncovered to be grasped). This overlooks the instability of politics and the fragility of political *agencements*, when the conceptual strength of STS approaches is their ability to seize such instabilities and fragilities. Issues may move back and forth between different modalities of political action.[146] I would even argue, as the case of French photovoltaic suggests, that several definitions of "political" action may co-exists, that is to say that political actions may deploy along several lines simultaneously.

Despite this limitation, this tentative classification is particularly interesting as an invitation to consider the full spectrum of political action, broadly defined as the activities that are concerned with the composition and organisation of "the common world" (Latour, 2007). It draws attention to the multiple practices and processes that

[145] For instance, Latour refers to "stages in the natural history of issues" (Latour, 2007, p. 818), or, in another analogy with natural science, writes that "in the same way as stars in astronomy are only stages in a series of transformations that astronomers have learned to map, issues offer up many different aspects depending on where they are in their life histories" (Latour, 2007, p. 815). This seems to suggest that the five meanings of "political" point to distinct stages and that issues are assumed to move towards their gradual stabilisation, following a form of "natural trajectory".

[146] Well-established procedures may collapse or be challenged by new, unexpected developments, silenced political *dispositifs* can be redeployed and contested, etc…

can be labelled as "political": the term political can refer to the definition of the common good, to more or less violent moments of disruption, upheaval or contestation, or to the routine administration of public affairs. None of these activities is intrinsically "more" political than the others; all are concerned with the management of public issues and the cohesion of the City, but they clearly involve different types of actors, organisations and practices.

Another merit of this perspective is that it puts *issues* at the centre: it is not interested so much in political action *per se* as in *the objects* of political action and in what is happening *to* them and *because of* them. Thus, rather than an attempt at a general definition of political action in STS terms, it is an invitation to consider the careers of specific issues by focusing on "two basic elements: *what* are the things politics should turn around and *how* it is going to turn around those things" (Latour, 2007, p. 819). Or, to rephrase it in the terms I have used so far, it can be understood as a proposition to consider issues as "political *agencements*". As much as each market transaction involves distinct, specific framings, each political issue calls for specific procedures, assemblies and modes of organisation that are costly to establish and maintain.

The emergence of photovoltaics in France in the light of feed-in tarifs. Exploring the markets and politics of a modular technology.

This thesis explores the recent evolutions of photovoltaics in France, and in particular the rise of grid-connected photovoltaics as it was triggered by support policies set up in the 2000s. The chosen actor-network theory approach leads to a material and relational descrption of French photovoltaics as modular technologies whose development was driven by political prices in the shape of feed-in tariffs for PV-generated electricity. From this perspective, the intertwinement of technological evolutions, market-making and politicisation is interrogated. After suggesting a description of photovoltaics as emergent and modular technologies and of feed-in tariffs as political market *agencements*, the thesis analyses the interwoven trajectories of feed-in tariffs and phootvoltaics in three sites. First, it traces back the constitution of feed-in tariffs as a dominant form of support for photovoltaics in the context of the development of a European policy for renewable energy. It then zooms on the French case, in which the overflowing of the regulated photovoltaic market triggered a political crisis and led to the reconsideration of photovoltaic support schemes. The last case study is a material account of the constitution of feed-in tariffs for PV-generated electricity into an opportunity and a resource for territorial development in the context of a project developed by a rural cooperative in the South West of France.

L'émergence du photovoltaïque en France à la lumière des tarifs d'achat. Exploration d'une technologie modulaire entre politiques et marchés.

Cette thèse explore les évolutions récentes du photovoltaïque en France, et en particulier l'essor rapide du photovoltaïque connecté au réseau qu'ont entrainé les politiques de soutien mises en place dans les années 2000. Dans une perspective relevant de la théorie de l'acteur-réseau, elle propose une description matérielle et relationnelle du photovoltaïque français comme technologie modulaire dont le développement a été porté par la mise en place de prix politiques, les tarifs d'achat. Cela amène à interroger les liens entre évolution technologique, mise en marché et mise en politique. Après une description du photovoltaïque comme technologie émergente et modulaire et des tarifs d'achat comme agencements marchands et politiques, la thèse analyse leur trajectoire dans trois sites. Une première étude de cas retrace la constitution des tarifs d'achat en instrument dominant de soutien au photovoltaïque dans le contexte de la mise en place des politiques européennes de développement des énergies renouvelables. On se penche ensuite sur le cas français, dans lequel les débordements du marché régulé du photovoltaïque ont déclenché une crise politique qui a remis en cause les dcispositifs de soutien. Enfin, une dernière étude de cas explore le travail de traduction des tarifs d'achat photovoltaïque en opportunité et en ressource territoriale à travers un projet photovoltaïque mutualisé mené par une coopérative agricole du Lot.